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DRAFT

Jerry Hansen

**Work Plan for an
Engineering Evaluation/Cost Analysis at
Site FT01 and Site SS12**



**King Salmon Airport
King Salmon, Alaska**

Prepared For

**Air Force Center for Environmental Excellence
Brooks Air Force Base
San Antonio, Texas**

and

**11th Civil Engineering Operations Squadron
Elemendorf Air Force Base
Anchorage, Alaska**

August 1994

AQ M01-01-0299

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**WORK PLAN FOR AN
ENGINEERING EVALUATION/COST ANALYSIS
IN SUPPORT OF INTRINSIC REMEDIATION
(NATURAL ATTENUATION) AT
SITES FT01 AND SS12
KING SALMON AIRPORT, ALASKA**

August 1994

Prepared for:

**AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE
BROOKS AIR FORCE BASE
SAN ANTONIO, TEXAS**

AND

**11th CIVIL ENGINEERING OPERATIONS SQUADRON
ELMENDORF AFB
ANCHORAGE, ALASKA**

Prepared by:

**Engineering-Science, Inc.
1700 Broadway Suite 900
Denver, Colorado 80290**

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SECTION 1

INTRODUCTION

This work plan was prepared by Engineering-Science, Inc. (ES) for the Air Force Center for Environmental Excellence (AFCEE). It presents the scope of work required for the collection of data necessary to conduct an engineering evaluation/cost analysis (EE/CA) for remediation of two fuel-hydrocarbon-contaminated ground water sites at King Salmon Airport (KSA), in King Salmon, Alaska. The two sites to be addressed in this work plan are Fire Training Area No. 1 (Site FT01) and the Upper Naknek site (Site SS12). Investigations have been previously undertaken at both sites as part of the U S Air Force (USAF) Installation Restoration Program (IRP).

Several remedial options will be evaluated during the EE/CA, including free product removal; ground water extraction, treatment, and re-injection (i.e., pump and treat); and intrinsic remediation with long-term monitoring (intrinsic remediation). All hydrogeologic and ground water chemical data necessary to evaluate the various remedial options will be collected under this program; however, this work plan is oriented primarily toward the collection of hydrogeologic data to be used as input into the Bioplume II® ground water model in support of the intrinsic remediation option for restoration of fuel-hydrocarbon-contaminated ground water.

As part of the EE/CA, the Bioplume II® modeling effort has three main objectives:

- To predict the future extent and concentration of a dissolved-phase contaminant plume by modeling the effects of advection, dispersion, sorption, and biodegradation;
- To assess the migration potential of dissolved-phase contamination to downgradient receptors; and

- To provide technical support for the intrinsic remediation remedial option at post-modeling regulatory negotiations.

Development of this work plan was based on discussions with representatives from the AFCEE, Elmendorf Air Force Base (AFB), KSA, the US Environmental Protection Agency/Robert S. Kerr Research Laboratory (USEPA/RSKERL) and ES at meetings held during the weeks of January 31, 1994 and June 13, 1994; on the statement of work (SOW) for this project; and on a review of existing site characterization data. The intrinsic remediation demonstration effort for this site will involve completion of several tasks which are described in the following sections.

All field work will follow the health and safety procedures presented in the program *Health and Safety Plan for the Bioplume II Modeling Initiative* (ES, 1993) and the site-specific addendum to the program Health and Safety Plan.

1.1 SCOPE OF CURRENT WORK PLAN

The objective of the work described herein is to provide an EE/CA for remediation of ground water contamination at sites FT01 and SS12 at KSA, Alaska. However, this project is part of a larger, broad-based initiative being conducted by AFCEE in conjunction with USEPA/RSKERL and ES to document the biodegradation and resulting attenuation of fuel hydrocarbons dissolved in ground water by indigenous microorganisms, and to model this degradation using the Bioplume II® numerical ground water model. For this reason, the work described in this work plan is directed toward collection of data in support of this initiative. All data required to develop a 30-percent design of an alternate remediation system, should intrinsic remediation not prove to be a viable remedial option at this facility, also will be collected under this program.

Proposed site characterization activities include identification of site utility locations, drilling and sampling soil borings and ground water monitoring wells, and aquifer testing. Drilling and well installation procedures, aquifer testing procedures, and soil and ground water sampling and analytical protocols are described herein. Existing site-specific data and data collected during the supplemental site characterization activities described in this work plan will be used as input for the Bioplume II® model. Where site-specific data are not available, conservative values for the types of aquifer materials present at the site will be obtained from widely accepted published literature and used for model input.

Sensitivity analyses will be conducted for the parameters with the greatest influence on the results of the Bioplume II® model, and where possible, the model will be calibrated to historical site data. Upon completion of the Bioplume II® model, ES will provide technical assistance at regulatory negotiations to support the intrinsic remediation option if the results of the modeling indicate that this approach is warranted. If it is shown that intrinsic remediation is not the most appropriate remedial option, ES will identify the most appropriate remedial option based on available data.

This work plan consists of six sections, including this introduction, and one appendix. Section 2 presents existing site-specific data and a conceptual model for each of the sites. Section 3 describes the proposed sampling strategy and procedures to be used to collect additional site characterization data. Section 4 describes the remedial option evaluation procedure and EE/CA report format. Section 5 describes the quality assurance/quality control (QA/QC) measures to be used during this project. Section 6 contains the references used in preparing this document. Appendix A lists the containers, preservatives, packaging, and shipping requirements for ground water samples.

1.2 INSTALLATION HISTORY

KSA is situated on a 216-acre site located on the upper, northwestern side of the Alaskan Peninsula (Figure 1.1). Anchorage, Alaska is 280 miles to the northeast. KSA is located on the northern bank of the Naknek River, facing Bristol Bay. The closest communities are the small towns of King Salmon, located adjacent to the northern boundary of KSA, and Naknek and South Naknek, located approximately 13 miles west-northwest of KSA along the Naknek River (Figure 1.2). KSA is accessible only by air or water.

KSA is a forward operating base and hosts the North American Aerospace Defense Command with a contingent of F-15 Eagles on alert missions rotated from Elmendorf AFB. Maintenance and support for the F-15s at KSA is provided by the 643rd Support Squadron. This squadron is directed by the 3rd Control Wing out of Elmendorf AFB. In addition to F-15s, KSA is a base for long-range radar connected to the North American Defense (NORAD) Regional Operations Control Center at Elmendorf AFB

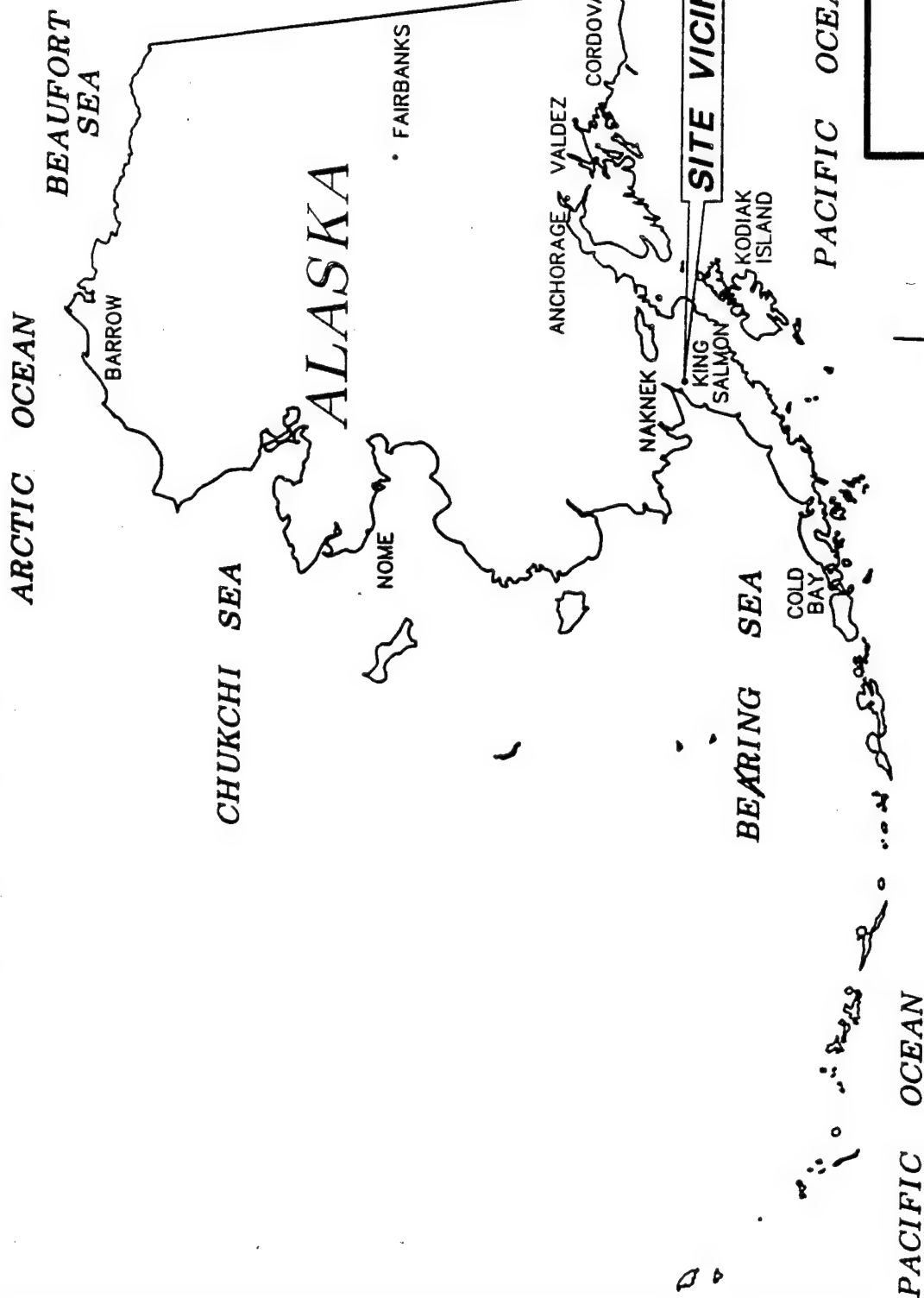


FIGURE 1.1

**LOCATION OF
KING SALMON AIRPORT**

KING SALMON AIRPORT, AK EE/CA

ENGINEERING-SCIENCE, INC.

Denver, Colorado

1.3 SITE BACKGROUND - FIRE TRAINING AREA NO. 1 (FT01)

The following information was gathered from recent remedial investigation/feasibility study (RI/FS) reports prepared by EMCON (1994b) and Science Applications International Corporation (SAIC, 1993b).

Site FT01 is located in the east-central portion of KSA, approximately 2,000 feet northeast of the intersection of the main runways. The fire training area has been in use since 1980 for fire training exercises that involved the use of fuels, solvents, oils, and fire retardant chemicals (ES, 1985). The main feature of the area is a circular pit approximately 50 feet in diameter. This pit is accessible by an adjacent road leading to the airport and the pit is approximately 800 feet due north and upgradient of Red Fox Creek. Figure 1.3 shows the location of Site FT01 relative to KSA.

For the purposes of this work plan, Site FT01 refers to the area including the fire training area and the plume of fuel-hydrocarbon-contaminated ground water extending south as far as Red Fox Creek. Figure 1.4 is a site map showing the FT01 vicinity in detail. Early IRP work identified the site in a Phase 1 records search as potentially contaminated (ES, 1985). Soil and ground water contamination in this area was first verified at the site during an airport-wide preliminary RI/FS involving 10 other sites including FT01 (SAIC, 1993b). No other quantitative characterization of this site was conducted prior to SAIC's 1992 RI/FS field work: Communications with airport personnel revealed that an aboveground storage tank (AST) was reportedly removed from the site on an undetermined date (SAIC, 1993b). Several other related IRP investigations involving FT01 have been conducted, reports of which are still in preparation and unavailable at the time of this report. The results of previous site investigations are covered in several reports, including:

- *Installation Restoration Plan, King Salmon Airport, Stage 1, Final Technical Report (CH2M Hill, 1989);*
- *Installation Restoration Plan, Stage 2, Final Draft Technical Report (CH2M Hill, 1990);*
- *Report of Ground Water Monitoring Well Sampling and Analysis, King Salmon Airport, Alaska (SAIC, 1992);*

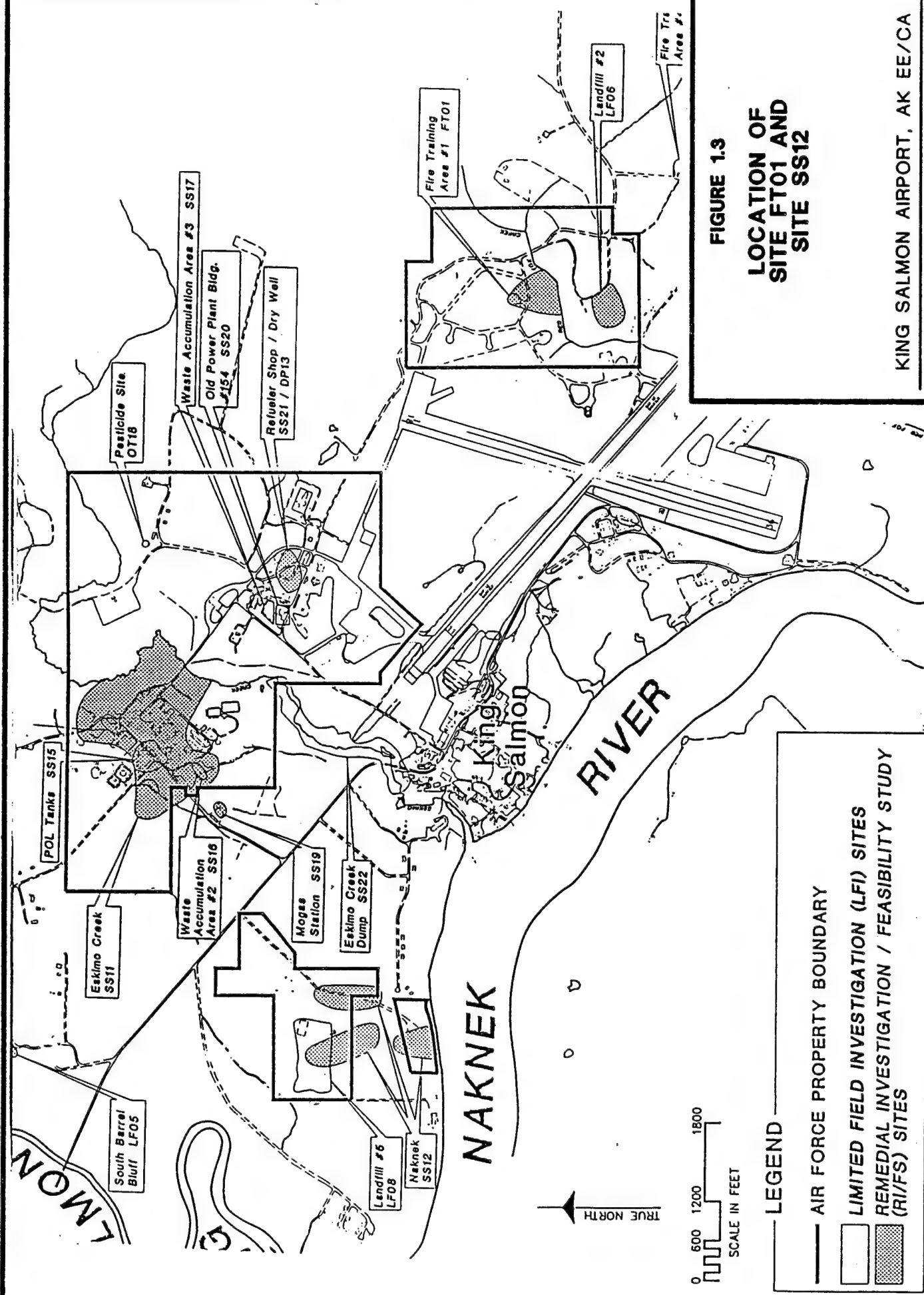


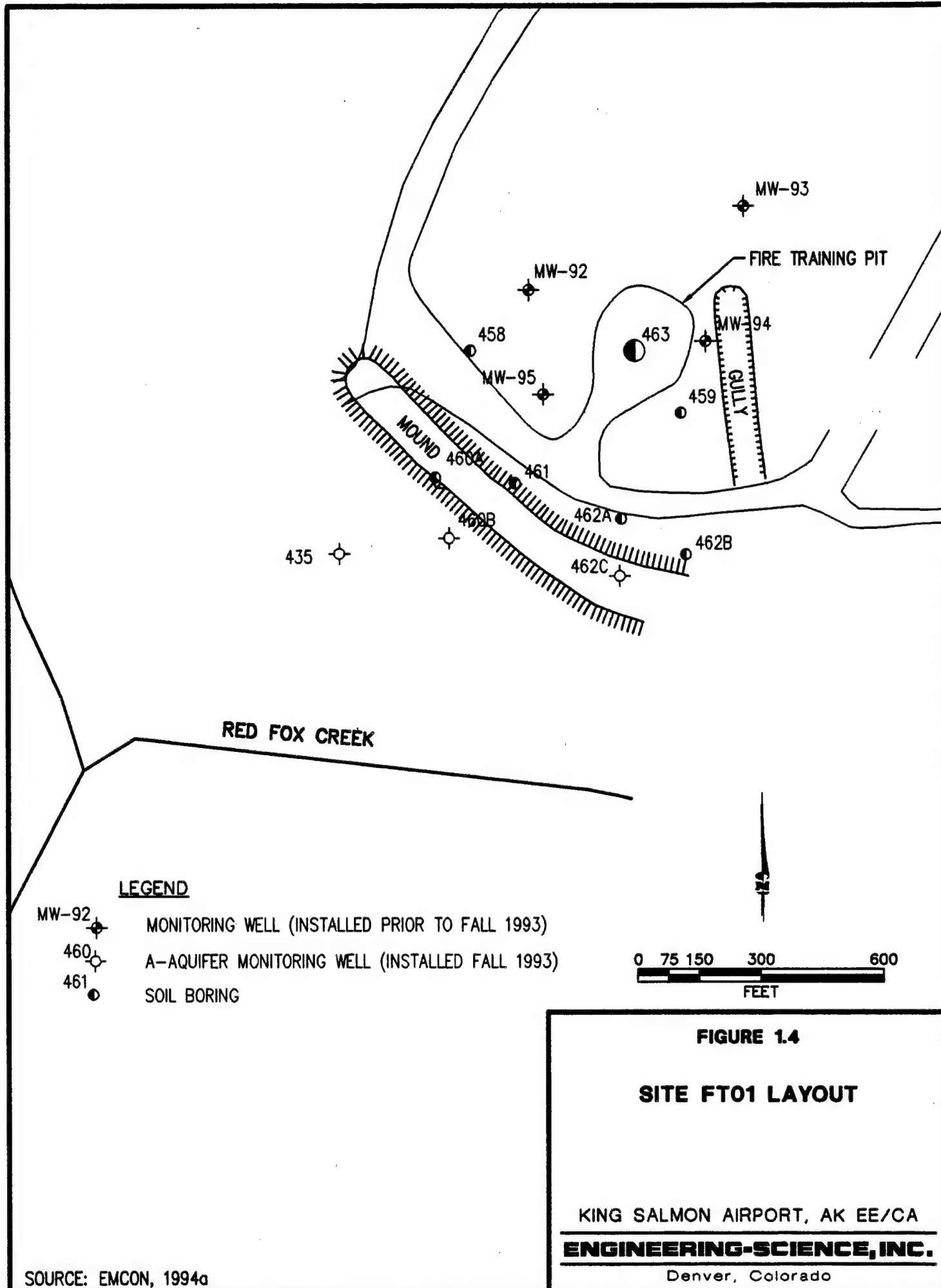
FIGURE 1.3

LOCATION OF
SITE FT01 AND
SITE SS12

KING SALMON AIRPORT, AK EE/CA
ENGINEERING-SCIENCE, INC.
Denver, Colorado

SOURCE: EMCON, 1994a

M: \45011\DRAWINGS\94DN0862, 08/26/94 at 10:54



SOURCE: EMCON, 1994a

- *Ground Water Monitoring Performed October 1992, King Salmon Airport, King Salmon, Alaska* (SAIC, 1993a);
- *Remedial Investigation/Feasibility Study at Eleven Sites, King Salmon Airport, King Salmon, Alaska* (SAIC, 1993b);
- *Remedial Investigation/Feasibility Study (RI/FS) at Twelve Sites, Stage 3, Part 1: Remedial Investigation, King Salmon Airport, King Salmon, Alaska* (EMCON, 1994a);
- *A September/October 1994 monitoring well sampling report (EMCON, 1994b-in preparation); and*
- *Remedial Investigation/Feasibility Study (RI/FS) at Twelve Sites, Stage 3, Part 2: Remedial Investigation, King Salmon Airport, King Salmon, Alaska (EMCON, 1994c-in preparation)*

The site-specific data and conceptual model presented in Section 2 are based on a review of available documents. A synopsis of site characterization activities conducted to date is provided by EMCON (1994a). As described in Section 2, diesel-range organics (DROs) and volatile organic compounds (VOCs) in ground water at the site occur at low concentrations and extend laterally approximately 500 feet downgradient from the training pit. Soil contamination appears to have an areal extent of approximately 800 square feet on the pit surface.

1.4 SITE BACKGROUND - UPPER NAKNEK SITE (SITE SS12)

The Upper and Lower Naknek Sites (collectively referred to as Site SS12) are located on the northern bank of the Naknek River approximately 0.7 mile west of the town of King Salmon, Alaska (Figure 1.3). Site SS12 was a petroleum, oil and lubricants (POL) tank farm where fuel was stored in ASTs and underground storage tanks (USTs). Fuel was supplied by barge up the Naknek River, where it was unloaded via pipeline to the tanks and stored until needed. Information is limited as to the number of tanks that have operated or are operating at the site. The ASTs at the Upper Naknek Site have been removed, and the status of the USTs at this site is uncertain. The USTs included 2,

25,000-gallon "Operation USTs," 24, 50,000-gallon USTs, and 24, 25,000-gallon USTs. There were also three, 25,000-barrel ASTs, and one, 11,900-barrel AST located at the Lower Naknek site. Another feature of interest is Landfill #5, which is located in the western portion of the Upper Naknek Site (Figure 1.5). This landfill is located adjacent to and overlaps the petroleum contamination from the Upper Naknek Site and has been targeted for a limited field study (LFS) (EMCON, 1994). The operational dates of the landfill are unknown, but it was reportedly used as a disposal area for empty drums.

The Upper Naknek Site will be studied under this EE/CA, and the areas of the former USTs and ASTs and the associated plume of fuel-hydrocarbon-contaminated ground water that extends south and southeast toward the Naknek River will be included (Figure 1.5). Field activities outlined in this work plan may reveal that petroleum contamination extends from the Upper to the Lower Naknek Sites. Potential former and current sources of contamination include ASTs, USTs, a waste pit, a truck stand, a dry well, and a sludge disposal area (EMCON, 1994a). No data are currently available to show the precise locations of these features.

During preliminary site investigations at the Upper Naknek Site, contamination was observed as a visible sheen of hydrocarbons on surface waters (ES, 1985). Site investigations performed by CH₂M Hill from 1987 to 1990 (CH₂M Hill, 1989 and 1990) included a soil gas survey; a geophysical survey; installation of seven monitoring wells, five shallow borings, and four back-hoe test pits; and completion of slug tests at seven monitoring wells. These activities confirmed the presence of a landfill at the western end of the site and concentrations of benzene exceeding the USEPA drinking water standard. In 1993, petroleum product seepage from the Upper Naknek Site was reported to be flowing into the Lower Naknek Site. SAIC constructed a french drain at the site to stop migration of contamination to the Naknek River (Figure 1.5). Further studies also have documented contamination at the site. The results of previous site investigations at SS12 are presented in the following reports:

- *Installation Restoration Plan, King Salmon Airport, Stage 1, Final Technical Report (CH2M Hill, 1989);*
- *Installation Restoration Plan, Stage 2, Final Draft Technical Report (CH2M Hill, 1990);*

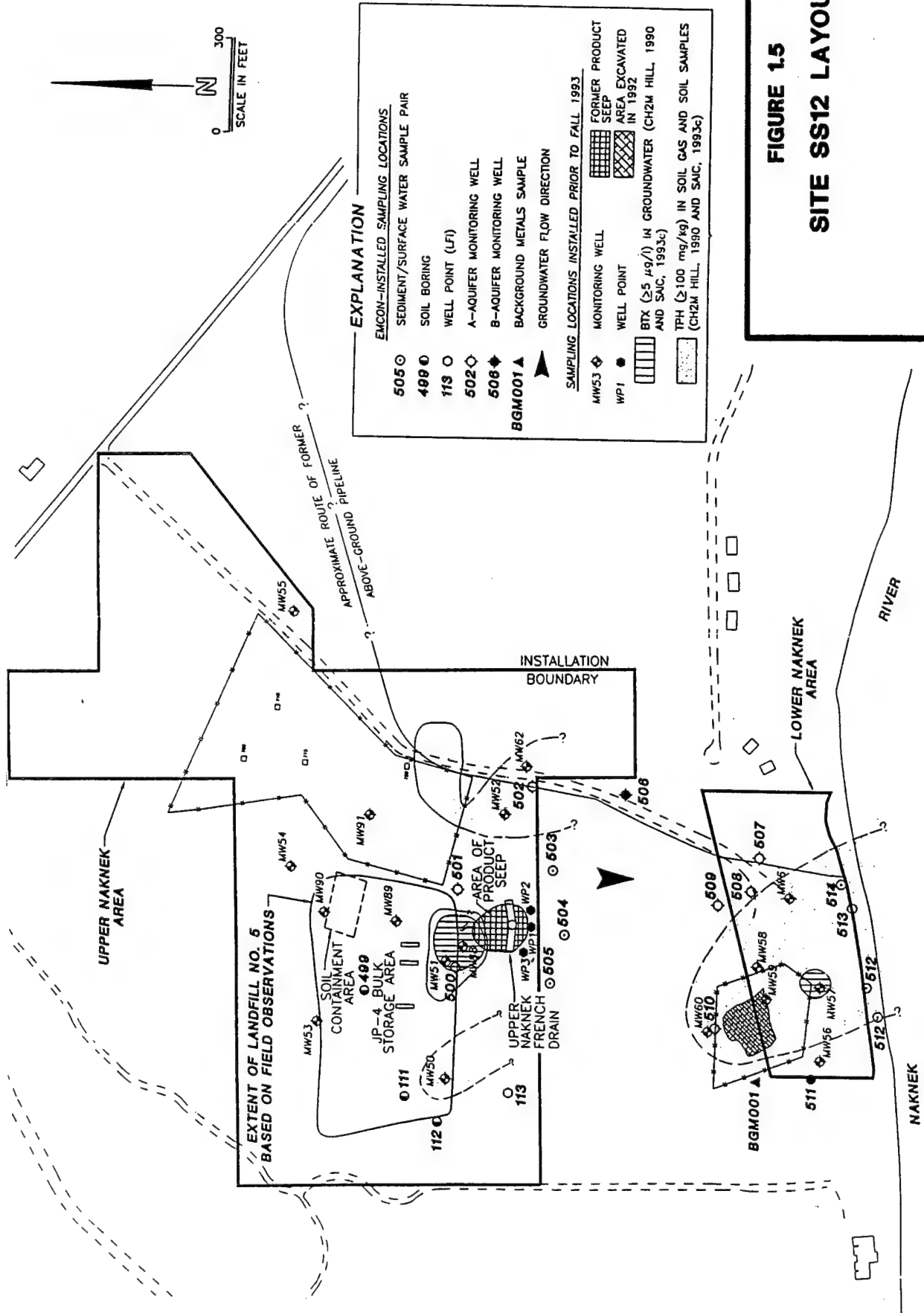


FIGURE 1.5
SITE SS12 LAYOUT

KING SALMON AIRPORT, AK EE/CA
ENGINEERING-SCIENCE, INC.
Denver, Colorado

- *Report of Ground Water Monitoring Well Sampling and Analysis, King Salmon Airport, Alaska* (SAIC, 1992);
- *Ground Water Monitoring Performed October, 1992, King Salmon Airport, King Salmon, Alaska* (SAIC, 1993a);
- *Remedial Investigation/Feasibility Study at Eleven Sites, King Salmon Airport, King Salmon, Alaska* (SAIC, 1993b);
- *Remedial Investigation/Feasibility Study (RI/FS) at Twelve Sites, Stage 3, Part 1: Remedial Investigation, King Salmon Airport, King Salmon, Alaska* (EMCON, 1994a);
- *A September/October, 1994 monitoring well sampling report, King Salmon Airport, King Salmon, Alaska, September/October 1994* (EMCON, 1994b-in preparation);
and
- *Remedial Investigation/Feasibility Study (RI/FS) at Twelve Sites, Stage 3, Part 2: Remedial Investigation, King Salmon Airport, King Salmon, Alaska* (EMCON, 1994c-in preparation)

The site-specific data and conceptual model for Site SS12 presented in Section 2, are based on a review of these documents.

SECTION 2

DATA REVIEW AND CONCEPTUAL MODEL DEVELOPMENT

Existing site-specific data were used to develop conceptual models for the ground water flow systems at the Upper Naknek Site and Site FT01. These conceptual models will allow additional data to be collected in a more efficient manner. Section 2.1 presents a synopsis of available site data, and Section 2.2 presents the conceptual models that were developed based on these data.

2.1 DATA REVIEW

The reports listed in Sections 1.3 and 1.4 were reviewed for data pertaining to Site FT01 and the Upper Naknek Site, respectively. Relevant portions of these reports are summarized in the following sections.

2.1.1 Climate

The King Salmon area experiences a transitional climate between the continental temperature extremes encountered in interior Alaska, and the milder coastal maritime climate. Mean annual temperature is 33 degrees Fahrenheit (°F), with a recorded range of minus 46°F in January to 88°F in June. Mean annual precipitation is approximately 20 inches. The majority of rainfall occurs in late summer and fall. Snowfall averages 46 inches per year, with a monthly recorded maximum of 20 inches in March. Discontinuous permafrost is encountered in the KSA area, with known occurrences east of the Upper Naknek area at Eskimo Creek and in the wetlands west of the Eskimo Creek/Naknek River confluence (Figure 1.2).

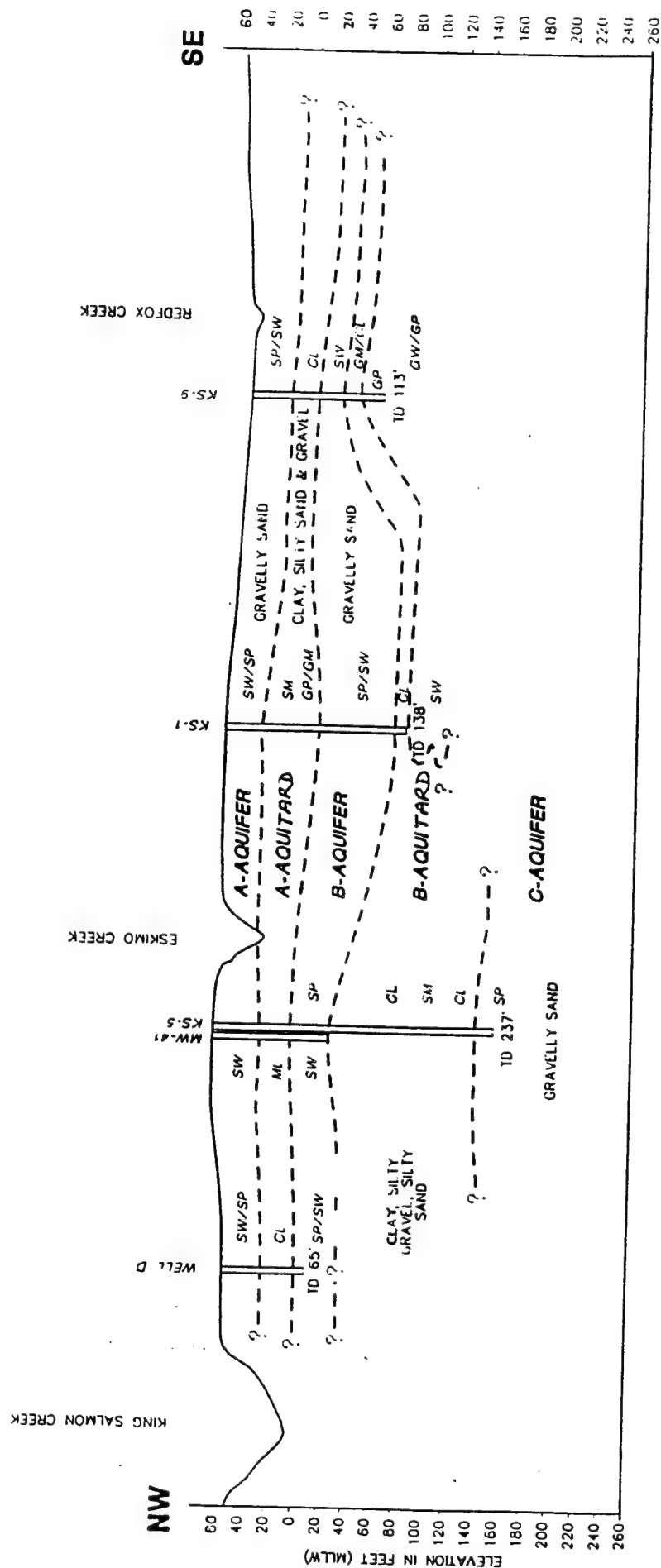
2.1.2 Overview of Geology and Hydrogeology

King Salmon is situated on a segmented volcanic arc of the Aleutian arc-trench system. This arc-trench system continues to form along the collision boundary between the northward-moving Pacific tectonic plate as it is subducted beneath the west/southwest-moving North American tectonic plate. Hence, the entire Alaska-Aleutian peninsula is an intensively active seismic zone. Within the eastern Aleutian arc, 10 of 22 volcanoes spanning the 336-mile-long volcanic front have erupted in recorded history and another six exhibit signs of hydrothermal activity. The rugged mountain peaks along the southeastern coast of the Alaskan Peninsula are the surface manifestation of volcanic rocks and distributed sediments from earlier, arc-related volcanoes. The lowland areas of the Alaskan Peninsula are generally mantled by Tertiary volcanic rock which has a low resistance to erosion, hence contributing to the subdued topographic expression of the Nushagak-Bristol Bay Lowland.

The upper few hundred feet of unconsolidated soils in the KSA area are comprised of glacially deposited Tertiary sediments. The deposits have been reworked by marine tidal, fluvial, and lacustrine processes, and include clay, silt, and sand. In general, three aquifers exist in the vicinity of KSA. The aquifers consist of unconsolidated well- to poorly-sorted, silty and gravely sands separated by aquitards (confining layers) consisting of silty and clayey gravels, silty sands, silts, and clays. A generalized cross-section of the area is shown in Figure 2.1.

The shallowest aquifer, the "A-Aquifer", is unconfined and exposed to the surface in nearly all locations at KSA. This aquifer is comprised of moderately well-sorted sands and silty sands with discontinuous lenses of medium- to coarse-grained gravel at the base. Static water level varies from the surface in creeks and wetlands to as much as 30 feet below ground surface (bgs) on the northern side of King Salmon Airport. Discontinuous permafrost may act as an impermeable barrier to the flow of ground water. The A-aquifer is likely recharged by precipitation and influent stream flow. The general flow pattern of ground water is toward topographically lower areas, streams, and wetlands. Hydraulic conductivitys were previously estimated to be between 15 ft/day and 1,370 ft/day with an average value of 350 ft/day (CH₂M Hill, 1990).

Underlying the A-Aquifer is a zone of lower hydraulic conductivity consisting of gravely, clayey silt and sandy silt. This unit is called the "A-Aquitard." The aquitard



EXPLANATION

KS	KING SALMON AIRPORT BASE PRODUCTION WELL
MW	MONITORING WELL
TD	TOTAL DEPTH
CL	UNIFIED SOIL CLASSIFICATION SYMBOL

FIGURE 2.1

GENERALIZED HYDROGEOLOGIC CROSS-SECTION FOR KING SALMON AIRPORT

KING SALMON AIRPORT, AK EE/CA

ENGINEERING-SCIENCE, INC.

Denver, Colorado

SOURCE: EMCON, 1994a

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varies from 7 to 22 feet thick, and was previously reported to locally disrupt and modify the regional unconfined ground water flow pattern for the A-Aquifer, especially in areas where the aquitard is thickest (SAIC, 1993).

Below the A-Aquitard is the "B-Aquifer." The top of the B-Aquifer is encountered between 50 and 80 feet bgs at KSA. The B-Aquifer is suspected to be a semiconfined aquifer and is comprised of interbedded sequences of silty sands, sandy gravels, and silty to sandy gravels. The potentiometric surface of the B-Aquifer in some wells is close to the A-Aquifer water table elevation in the same or neighboring wells. Ground water movement in the B-Aquifer is generally to the south.

Between the B-Aquitard and the next aquifer is a second aquitard called the "B-Aquitard." The thickness of this second aquitard is estimated to be between 10 and 120 feet. This unit is predominantly sandy clay.

Limited data are available concerning the third water-bearing unit at the site, the "C-Aquifer". The C-Aquifer underlies the B-Aquitard at approximately 200 feet bgs. This aquifer also is suspected to be confined. KSA water supply wells are completed in the C-Aquifer. The thickness of this aquifer is unknown, but may be up to 20 feet based on data from water supply well No. 5 at KSA. No data are available concerning the direction of ground water flow in the C-Aquifer.

2.1.2.1 Site-Specific Geology and Hydrogeology - Fire-Training Area (FT01)

The fire training area was investigated by SAIC in 1993, at which time 38 soil gas monitoring points were installed and sampled. To date, 11 boreholes and 7 monitoring wells have been completed in the immediate vicinity of the fire training pit at the site. Figure 2.2 shows the locations of the soil-borings (some of which were completed as monitoring wells), and the locations of hydrogeologic sections A-A' and C-C'. Table 2.1 presents currently available well and piezometer completion information for sites FT01 and SS12, and currently available ground water elevation data. Figure 2.3 presents hydrogeologic sections A-A' and C-C' for FT01 and shows the relationship between the ground water surface and the stratigraphy at the site. Figure 2.4 illustrates the ground water elevations at the site estimated from fall 1993 data. Figure 2.5 illustrates the approximate thickness of the A-Aquifer in the vicinity of Site FT01.

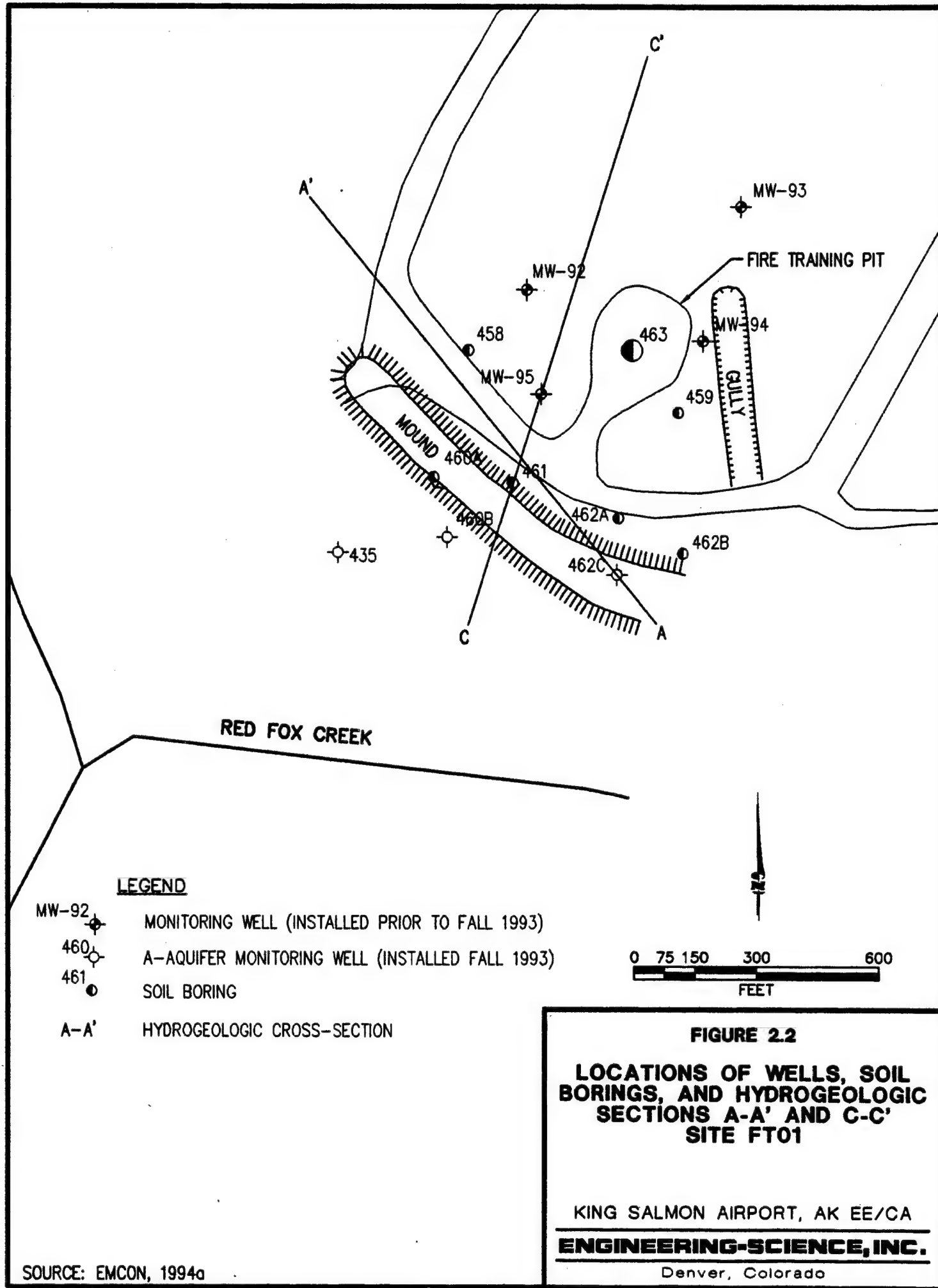


TABLE 2.1

**WELL COMPLETION INFORMATION
SITES FT01 AND SS12
KING SALMON AIRPORT, ALASKA**

USAF Site Code	Sample Location	Installation Date	Northing	Easting	Completion Aquifer	Well Diameter (inches)	Casing Type	Screen Interval Top (ft bgs)	Screen Interval Bottom (ft bgs)	Total Depth to Water (ft bgs)	Ground Elevation (ft mllw)
LF006	435	10/19/93	1711990.76	189850.28	A	2	PVC	15.0	25.0	19	62.7
FT001	460B	10/14/93	1712042.18	1898974.99	A	2	PVC	9.0	19.0	15	60.4
FT001	462C	10/14/93	1712050.58	1899192.20	A	2	PVC	4.0	14.0	5	51.5
FT001	MW-92	9/26/92	1712401.24	1898994.67	A	4	PVC	9.0	29.0	18	63.4
FT001	MW-92	10/12/92	1712401.24	1898994.67	A	4	PVC	NA	NA	17.85	47.15
FT001	MW-93	9/26/92	1712532.79	1899212.65	A	4	PVC	5.0	25.0	13	58.9
FT001	MW-93	10/12/92	1712532.79	1899212.65	A	4	PVC	NA	NA	12.75	49.21
FT001	MW-94	9/27/92	1712369.16	1899238.12	A	4	PVC	6.0	26.0	13	58.7
FT001	MW-94	10/12/92	1712369.16	1899238.12	A	4	PVC	NA	NA	13.02	47.73
FT001	MW-95	9/28/92	1712261.66	1899039.23	A	4	PVC	7.5	27.5	14	58.9
FT001	MW-95	10/12/92	1712261.66	1899039.23	A	4	PVC	NA	NA	13.79	46.83
SS012	500	10/25/93	1714458.75	1889692.43	A	2	PVC	10.0	20.0	16	37
SS012	500	10/25/93	1714458.75	1889692.43	A	2	PVC	10.0	20.0	16	37
SS012	500	10/25/93	1714458.75	1889692.43	A	2	PVC	10.0	20.0	16	37
SS012	501	10/25/93	1714452.63	1889943.23	A	2	PVC	5.0	15.0	13	33.3
SS012	502	10/25/93	1714212.06	1890283.53	A	2	PVC	1.0	11.0	2	20.3
SS012	506	11/9/93	1713907.68	1890261.42	B	2	PVC	23.0	33.0	3	18.6
SS012	507	10/24/93	1713467.68	1890061.57	A	2	PVC	2.0	12.0	4	17.1
SS012	508	10/24/93	1713493.57	1889952.16	A	2	PVC	2.0	12.0	7	19
SS012	509	10/24/93	1713602.09	1889905.93	A	2	PVC	3.0	13.0	7	21.4
SS012	510	10/24/93	1713608.03	1889508.34	A	2	PVC	3.0	13.0	16	23.3
SS012	MW-50	8/14/89	1714488.00	1889331.00	A	2	PVC	4.3	14.3	10	34
SS012	MW-51	8/14/89	1714472.00	1889776.00	A	2	PVC	6.7	16.7	10	32
SS012	MW-52	8/13/89	1714359.00	1890230.00	A	2	PVC	0.25	9.8	4	24
SS012	MW-53	7/30/89	1714912.00	1889489.00	A	2	PVC	9.9	19.9	16	43
SS012	MW-54	8/12/89	NA	NA	A	2	PVC	8.3	18.3	15	42
SS012	MW-55	8/2/89	NA	NA	A	2	PVC	10.9	20.9	15	43
SS012	MW-56	8/17/89	NA	NA	A	2	PVC	1.5	6.5	5	17
SS012	MW-57	8/6/89	NA	NA	A	2	PVC	0.0	10.0	6	17
SS012	MW-58	8/16/89	NA	NA	A	2	PVC	0.4	10.4	5	18
SS012	MW-59	8/16/89	NA	NA	A	2	PVC	1.2	11.2	4	19
SS012	MW-60	8/15/89	NA	NA	A	2	PVC	1.6	11.6	8	23
SS012	MW-61	8/8/89	NA	NA	A	2	PVC	2.4	7.4	7	17
SS012	MW-62	8/8/89	NA	NA	A	2	PVC	0.5	4.5	2	20
SS012	MW-88	9/3/92	1714469.00	1889849.00	A	2	PVC	8.0	28.0	10	34
SS012	MW-89	9/4/92	1714749.00	1889895.00	A	4	PVC	8.0	28.0	10	37
SS012	MW-90	9/7/92	1714912.00	1889863.00	A	4	PVC	9.0	29.0	16	44.5
SS012	MW-91	9/28/92	1714779.00	1890198.00	A	4	PVC	4.0	24.0	12	37.6

Sources: EMCON, 1994a & SAIC, 1993b.

NA=Not Available.

mllw=Mean lower low water.

ft bgs=feet below ground surface.

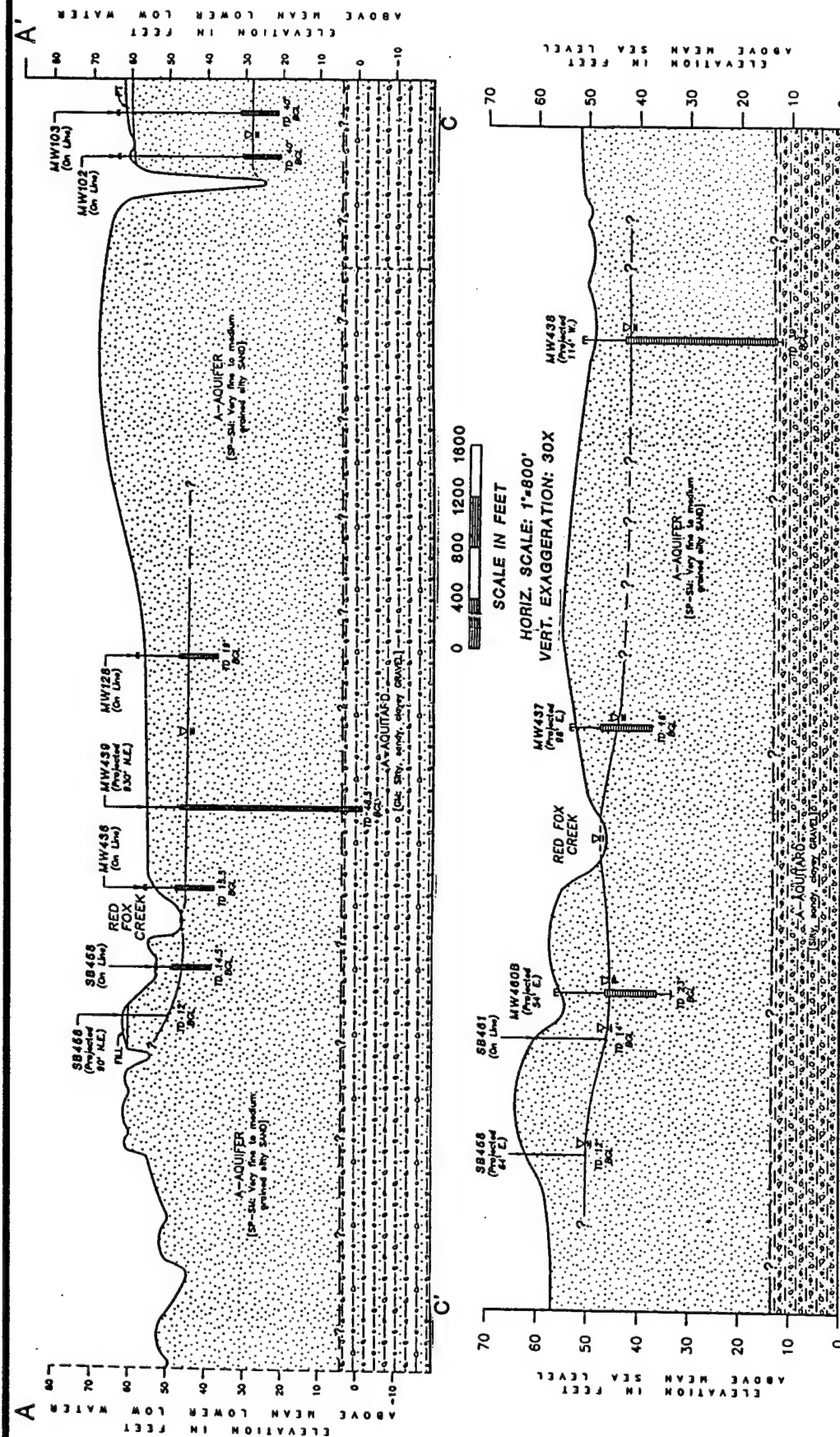
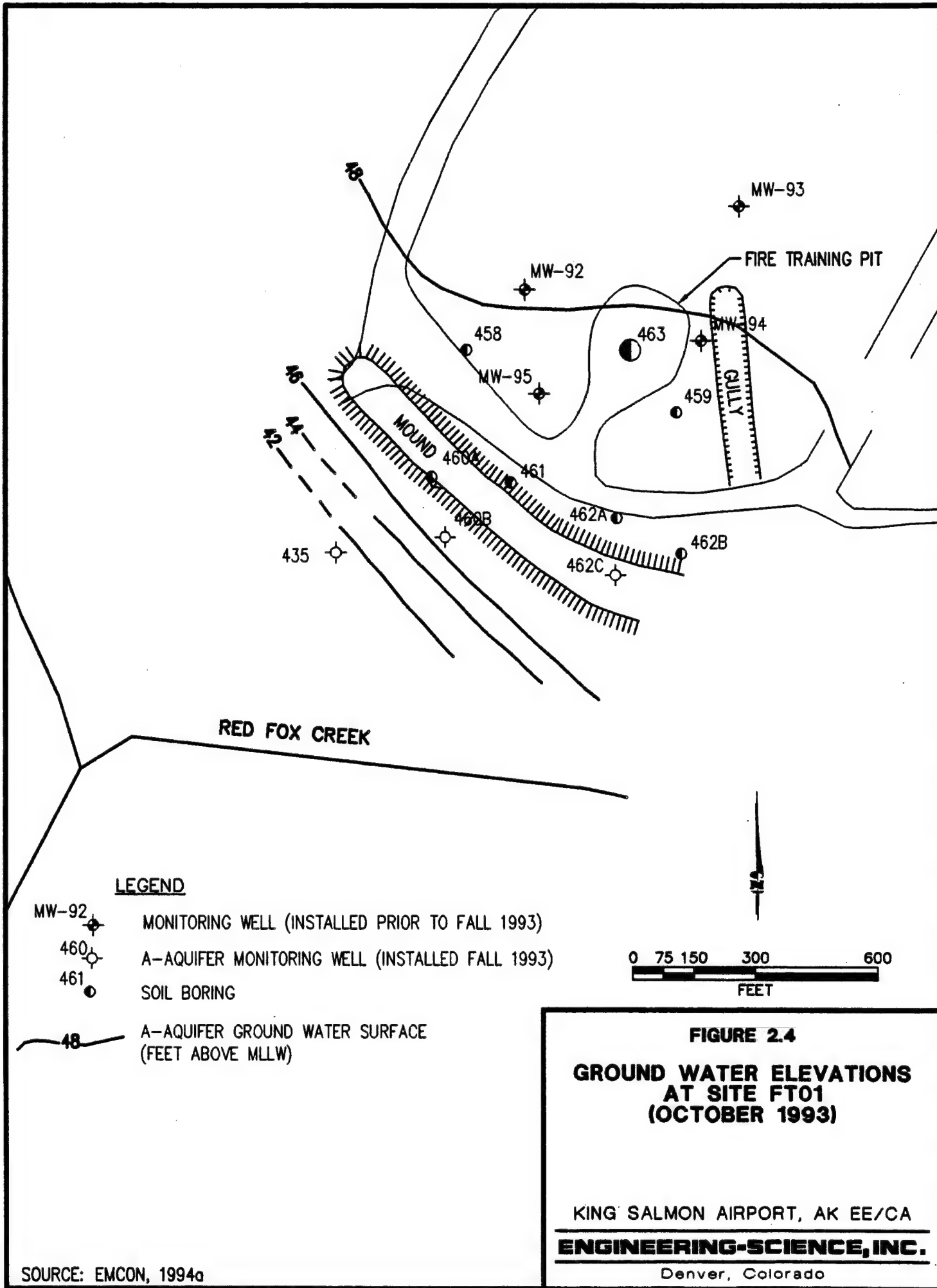
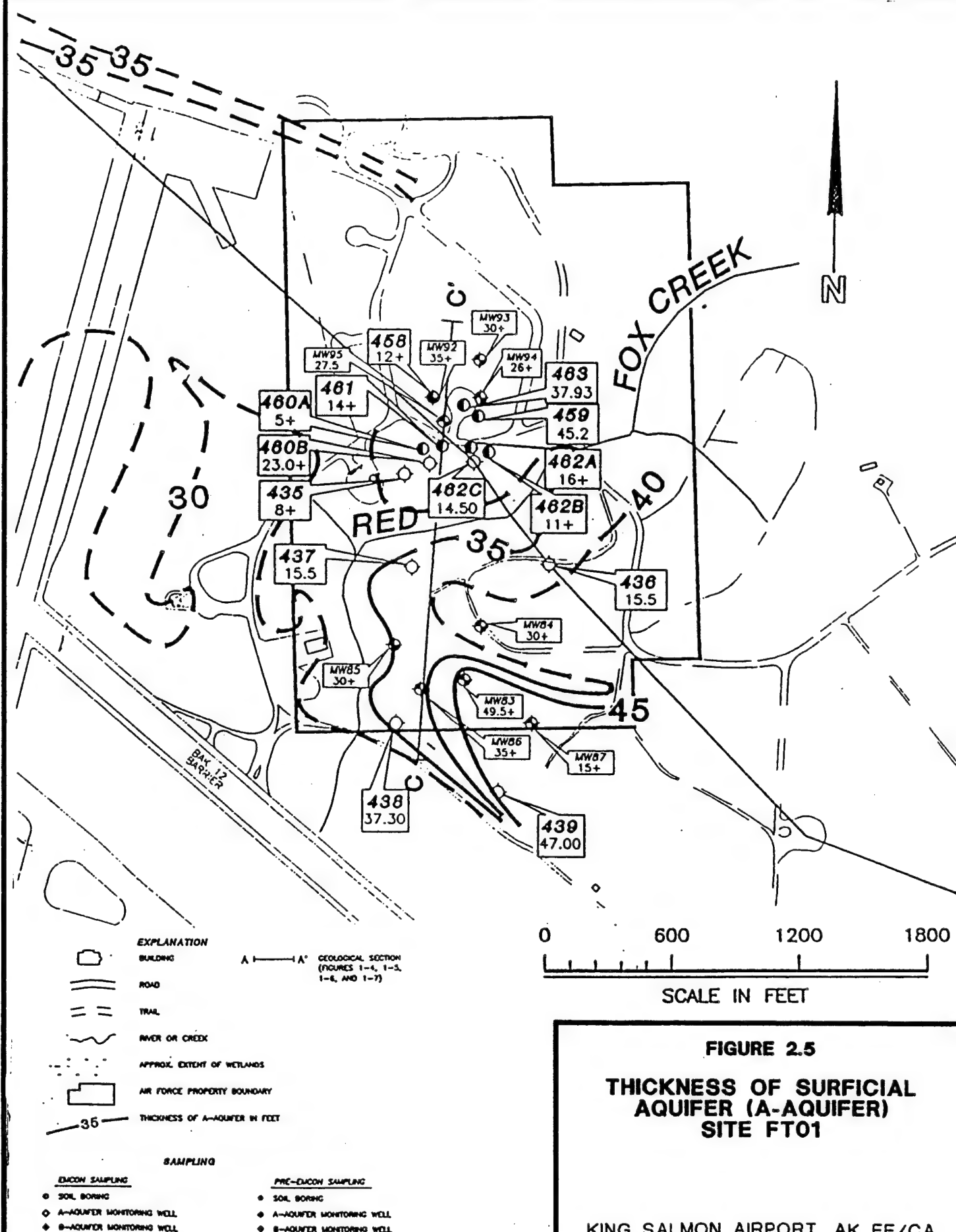


FIGURE 2.3

HYDROGEOLOGIC SECTIONS A-A' AND C-C' SITE FT01

KING SALMON AIRPORT, AK EE/CA
ENGINEERING-SCIENCE, INC.
Denver, Colorado





SOURCE: EMCON, 1994a

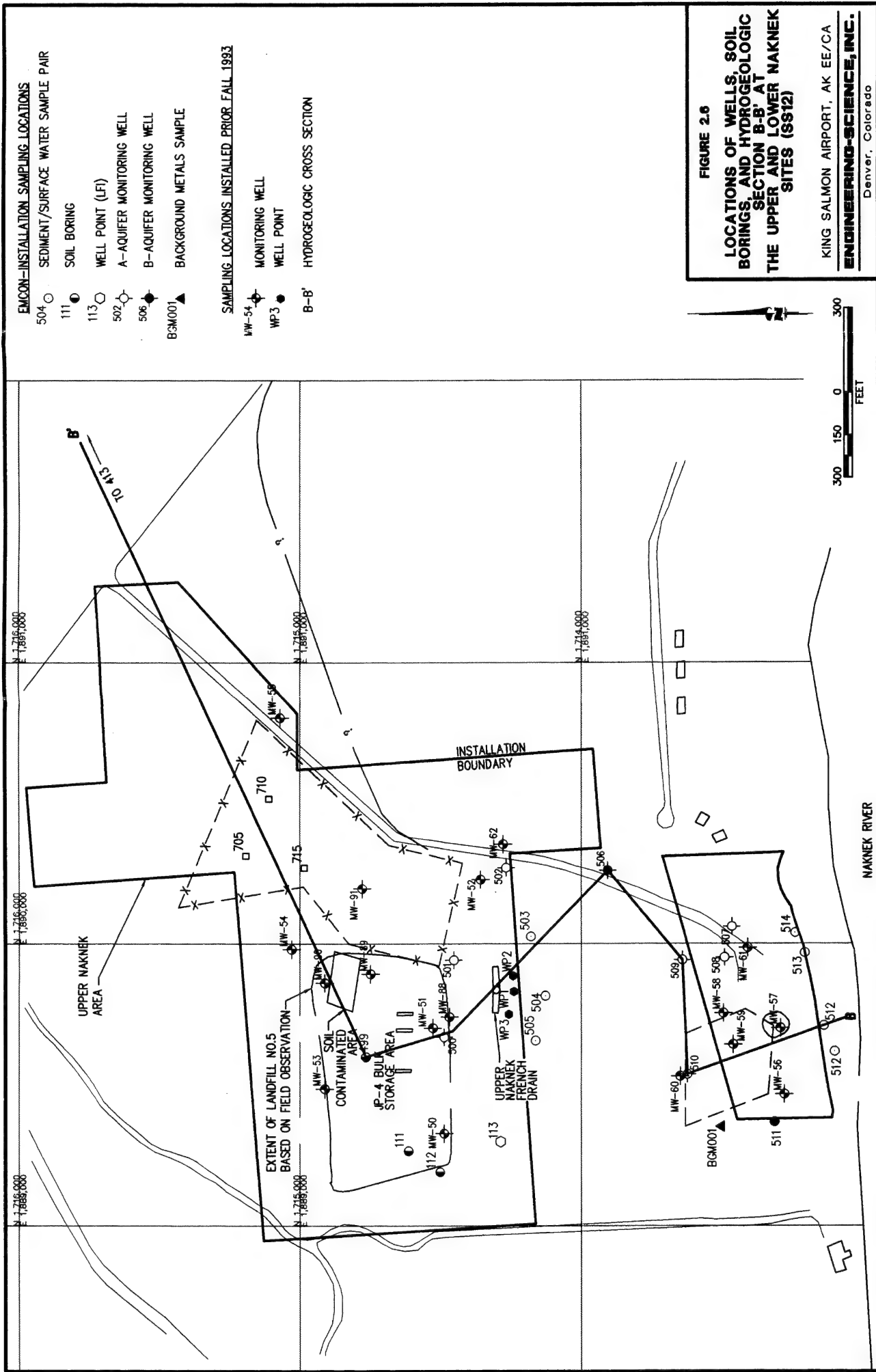
The shallow subsurface at site FT01 consists of a very-fine- to medium-grained silty sand. The aquifer thickness is believed to be as great as 50 feet. The underlying A-Aquitard is comprised of silty, sandy, clayey gravel. The saturated thickness of the aquifer, based on ground water data at the site, appears to be between 30 and 35 feet. The ground water gradient is roughly 0.005 foot per foot (ft/ft) to the southwest toward Red Fox Creek. Red Fox Creek intersects the aquifer, and acts as either a recharge or a discharge point, depending on seasonal rainfall and drainage.

2.1.2.2 Site-Specific Geology and Hydrogeology - Upper Naknek Site (SS12)

Characterization of the vadose zone and shallow aquifer system at the Upper Naknek Site has been the objective of several investigations. To date, at least 14 soil borings and 16 ground water monitoring wells have been completed in the vicinity of the Upper Naknek Site and the hydrocarbon plume emanating from that area. Figure 2.6 shows the locations of borings, wells, and hydrogeologic section B-B'. Table 2.1 presents available monitoring well and piezometer completion information and currently available ground water elevations. Figure 2.7 is hydrogeologic section B-B' which shows the relationship between the ground water surface and the stratigraphy at the site. Figure 2.8 depicts the ground water surface of the shallow A-Aquifer. Figure 2.9 illustrates the estimated thickness of the A-Aquifer in the vicinity of Site SS12.

Ground water is at or near the surface in the southern portion of the Upper Naknek Site (Figure 2.7). The soil matrix conforms to regional soil characteristics: very-fine- to medium-grained, occasionally coarse, silty sands. The aquitard consists of silty, clayey, and sandy gravels. Hydraulic conductivity data are not available for the site.

As previously mentioned, ground water at the Upper Naknek Site is near the surface. October 1993 water level data suggest that ground water in this area flows to the south with a gradient of approximately 0.01 ft/ft. Slug tests have been performed at the site (EMCON, 1994c), but these data were not available at the time this work plan was prepared.



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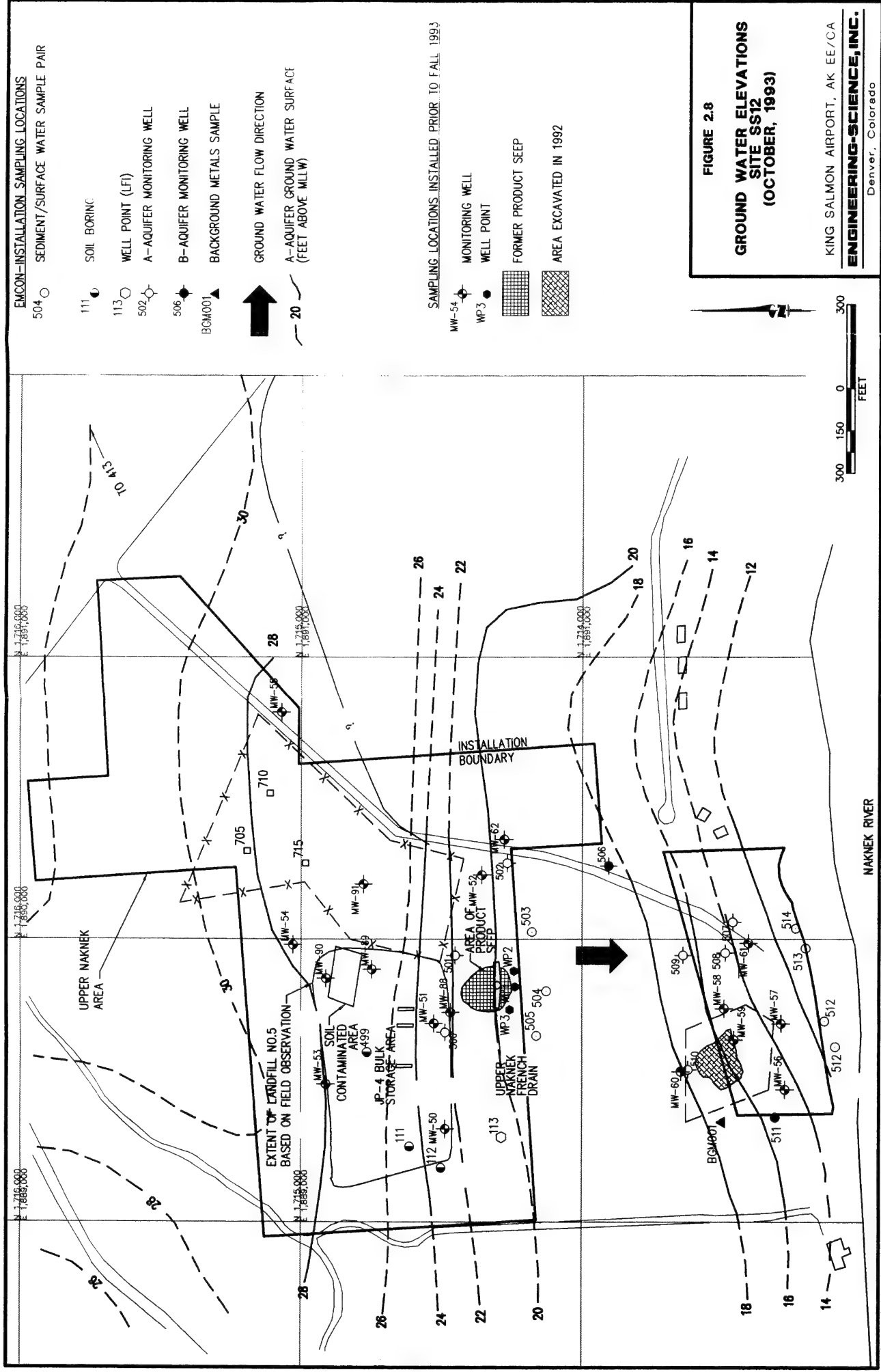
7 11

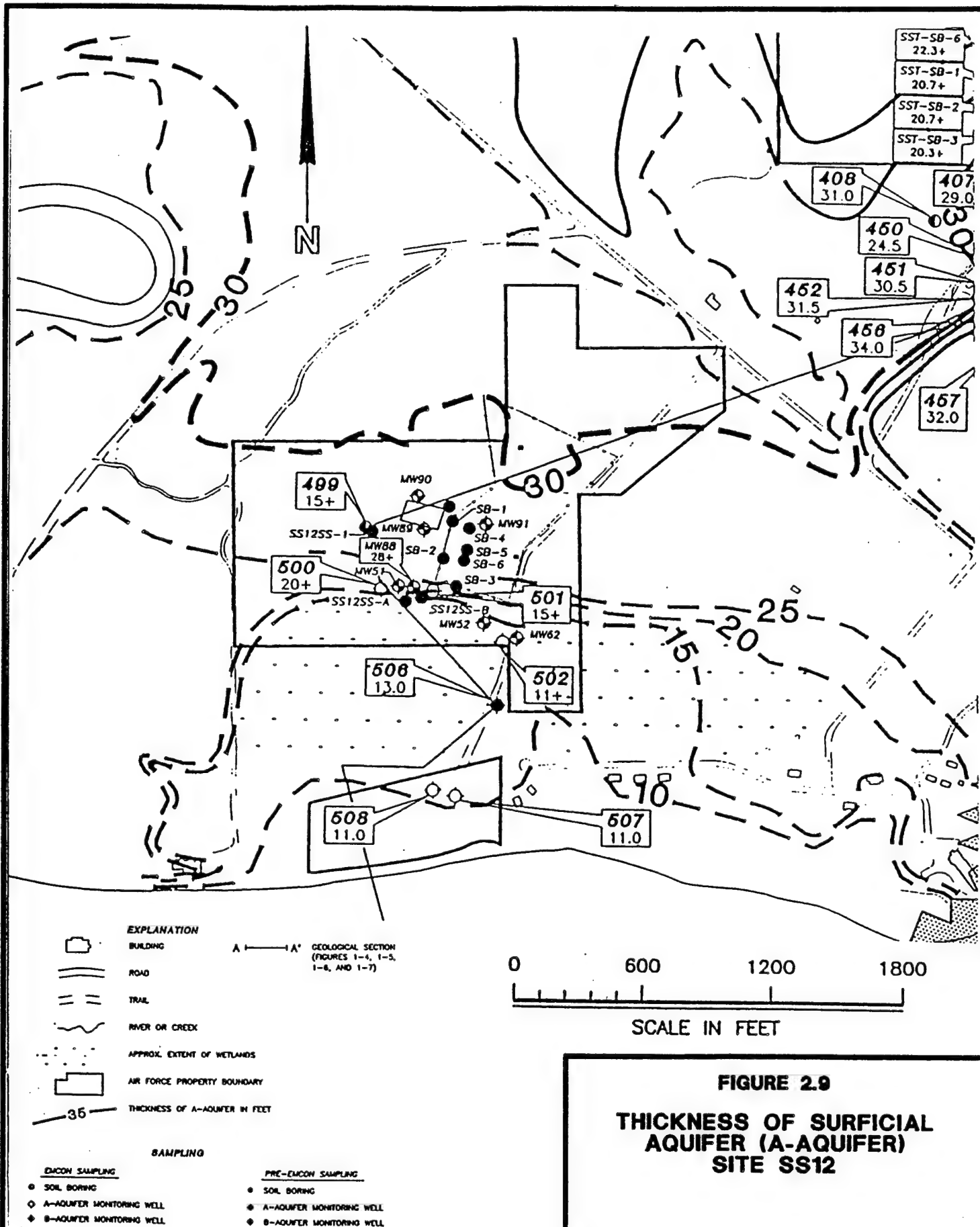
EMCON-INSTALLATION SAMPLING LOCATIONS
 504 ○ SEDIMENT/SURFACE WATER SAMPLE PAIR
 111 ● SOIL BORING
 113 ○ WELL POINT (LF)
 502 ○ A-AQUIFER MONITORING WELL
 506 ● B-AQUIFER MONITORING WELL
 BSM001 ▲ BACKGROUND METALS SAMPLE
 MW-54 ● MONITORING WELL
 WP3 ● WELL POINT
 B-B' HYDROGEOLOGIC CROSS SECTION

SAMPLING LOCATIONS INSTALLED PRIOR FALL 1993

FIGURE 2.6
LOCATIONS OF WELLS, SOIL BORINGS, AND HYDROGEOLOGIC SECTION B-B' AT THE UPPER AND LOWER NAKNEK SITES (S912)

KING SALMON AIRPORT, AK EE/CA
ENGINEERING-SCIENCE, INC.
 Denver, Colorado





SOURCE: EMCON, 1994a

2.1.3 Soil Quality

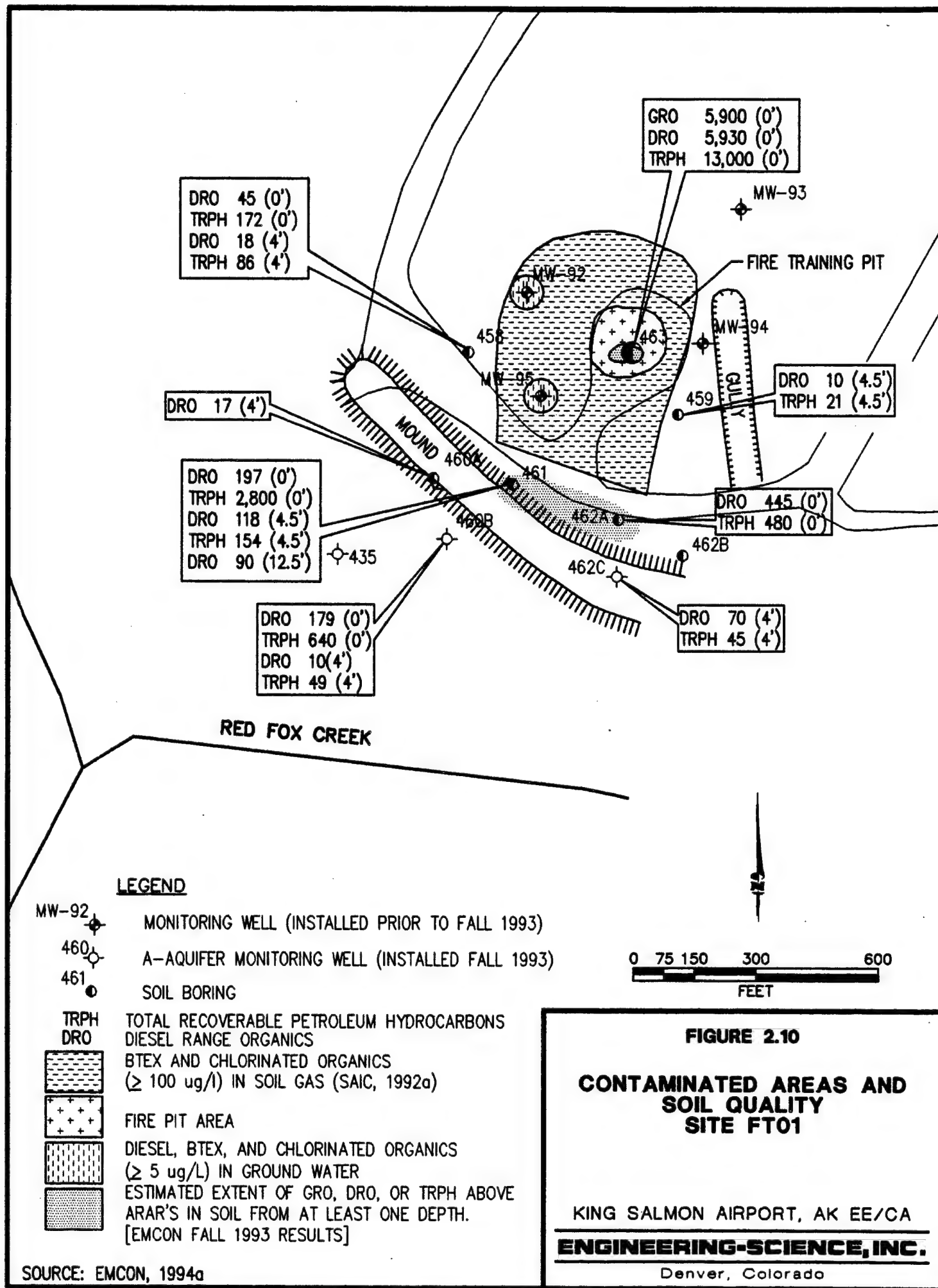
Available analytical data indicate that soils at both sites have soils contaminated with petroleum hydrocarbons. No measurable free product has been recorded at FT01. Product has seeped from the Upper Naknek Site along its southern edge.

2.1.3.1 Soil Quality - Fire Training Area #1 (FT01)

To date, Site FT01 has undergone two site investigations. Thirty-eight soil gas survey locations, 28 subsurface soil samples, and 1 surface soil sample have been collected and 7 monitoring wells have been installed in the vicinity of the fire training pit. At least nine of the soil borings were completed as monitoring wells. During installation of wells and borings in the fire training area, soil samples were submitted to a laboratory for a wide variety of chemical analyses. Table 2.2 contains a summary of available soil quality analytical results from the most recent investigation at the site (EMCON, 1994a).

Results of the soil gas study indicate the presence of benzene, toluene, ethylbenzene, and xylene (BTEX) and chlorinated organic compounds in the shaded area shown in Figure 2.10. Figure 2.11 shows the estimated extent of soil contamination at this site. Maximum VOC concentrations were 280,000 micrograms per liter ($\mu\text{g/L}$) methylethyl ketone (MEK); 77,000 $\mu\text{g/L}$ benzene; 69,000 $\mu\text{g/L}$ total xylenes; 57,000 $\mu\text{g/L}$ toluene; 49,000 $\mu\text{g/L}$ ethylbenzene; 520 $\mu\text{g/L}$ trichloroethene (TCE); and 890 $\mu\text{g/L}$ 1,1-dichloroethane (DCA). Soil analytical results obtained during installation of the first monitoring wells at the site (SAIC, 1993a) revealed the presence of VOCs and semivolatile organic compounds (SVOCs) in only one of the soil samples collected. This sample was collected at a depth of 10.5 to 11.5 feet bgs at MW-95, which is located approximately 100 feet southwest of the fire training pit (Figure 2.2). In this sample, ethylbenzene was detected at a concentration of 21.0 $\mu\text{g/kg}$; xylenes at 1.3 $\mu\text{g/kg}$; 2-methylnaphthalene at 2400 $\mu\text{g/kg}$; and naphthalene at 900 $\mu\text{g/kg}$. DROs were also measured at 360,000 $\mu\text{g/kg}$ in the sample (SAIC, 1993a).

Additional soil sampling by EMCON (1994a) indicated the presence of VOC contamination in four subsurface soil samples from soil borings 458, 460, 461, and 463. Toluene was detected in soil borings 458, 461, and 463, with the lowest detected concentrations being 4 $\mu\text{g/kg}$ and the highest being 29 $\mu\text{g/kg}$. Acetone was detected in a single sample at soil boring 460 at a concentration of 170 $\mu\text{g/kg}$. Total xylenes were



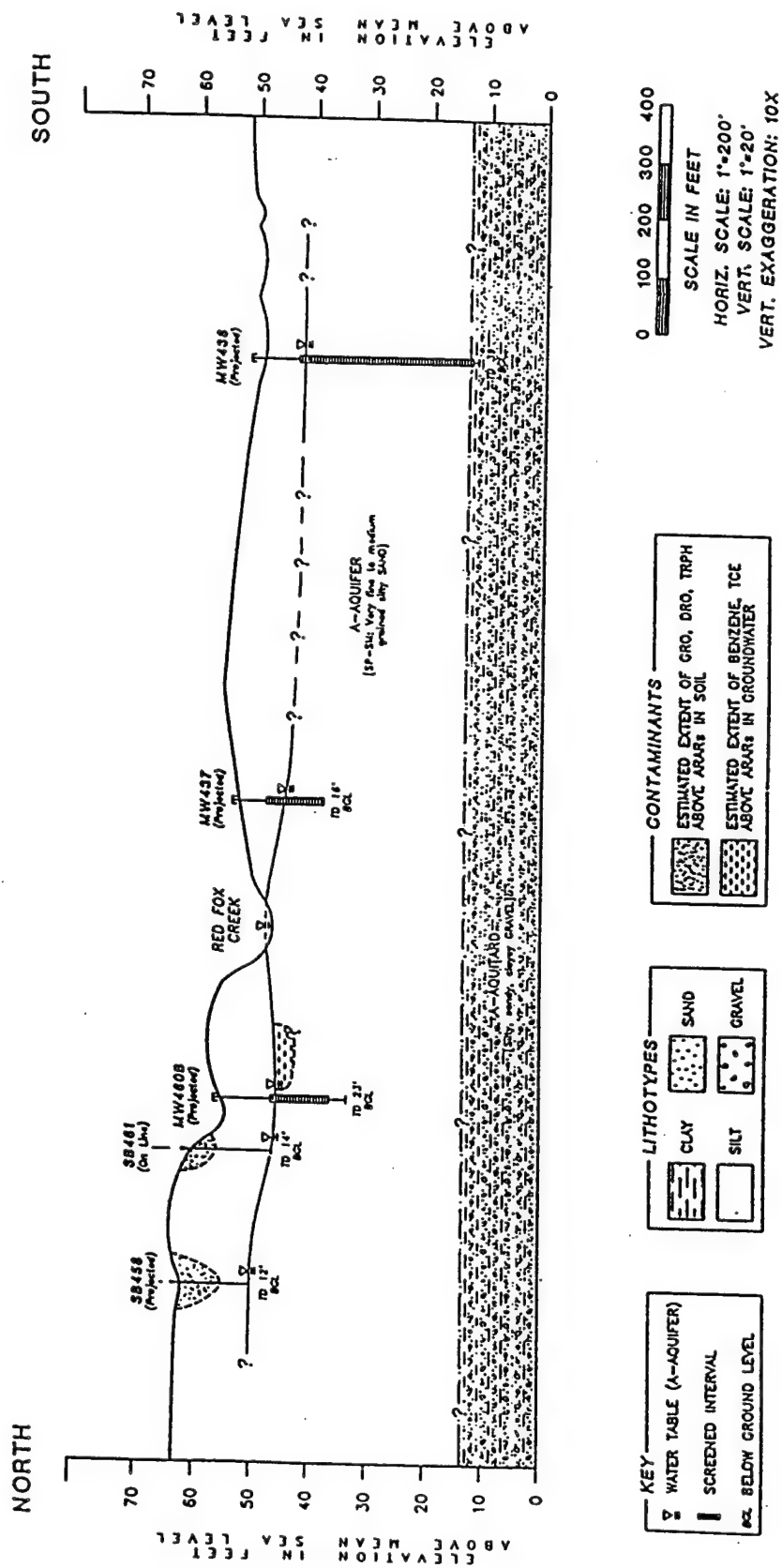


FIGURE 2.11

VERTICAL PROFILE OF SOIL CONTAMINATION SITE FT01

KING SALMON AIRPORT, AK EE/CA

ENGINEERING-SCIENCE, INC.

Denver, Colorado

SOURCE: EMCON, 1994a

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detected in two soil samples at concentrations ranging from 12 µg/kg in soil boring 458 to 75 µg/kg in soil boring 463. Most of the VOC contamination was limited to the top 5 feet of soil at the site.

Total recoverable petroleum hydrocarbons (TRPH) were detected at elevated concentrations in 10 of the 19 soil samples taken during the 1993 site characterization work conducted by EMCON. The range of concentrations was from 21 milligrams per kilogram (mg/kg) in soil boring 459 to 13,000 mg/kg in soil boring 463 (Table 2.2). The high concentration in soil boring 463 occurred in the top 1 foot of the soil matrix. DROs were detected in 12 of the 19 soil samples at concentrations ranging from 10 mg/kg at soil boring 459 to 5,930 mg/kg in soil boring 463. Similar to the TRPH contamination, the highest recorded level of DRO was in the top layer of soil at soil bore 463. Based on these results, it appears that the majority of the soil contamination occurs in the fire training pit and at locations downgradient of the pit. The highest observed contamination in all of the soil samples was in the top 1 foot of soil.

2.1.3.2 Soil Quality - Upper Naknek Site (SS12)

Preliminary soil characterization at the Upper Naknek Site was performed by CH₂M Hill (1989). This investigation involved a soil gas survey at two locations, one surface water sample collected from a spill excavation, and a conductivity/magnetic geophysical survey near landfill No. 5. The geophysics indicated buried material on the western side of the Upper Naknek Site (Landfill No. 5). This investigation indicated that petroleum hydrocarbon contamination existed at SS12, but did not define its nature or extent.

In 1990, CH₂M Hill performed more extensive characterization studies at the site, including geophysical surveys and additional soil sampling. The area of Landfill No. 5 was more accurately defined by the survey, and an area of buried debris was identified east of the road between the Upper and Lower Naknek Sites (near the old pipeline corridor). Elevated TRPH concentrations in the soil gas were encountered at the Upper Naknek Site in both soil gas points and in soil borings, hand augers, and test pits. Elevated TRPH concentrations were encountered in three locations surrounding MW50, MW88, and MW52. The easternmost TRPH area may be associated with the pipeline corridor. The other areas of elevated TRPH are probably associated with releases from USTs, ASTs, drums, or pipelines.

TABLE 2.2

**SOIL ANALYTICAL DATA
SITE FT01
KING SALMON AIRPORT, ALASKA**

Sample Location	Sample Date	Northing	Easting	Sample Depth (feet)	Sample Type	Diesel (mg/kg)	TRPH (mg/kg)	Benzene (µg/kg)	Toluene (µg/kg)	Ethylbenzene (µg/kg)	Total Xylenes (µg/kg)	Total BTEX (µg/kg)	Total Phosphorus (mg/kg)	Total Organic Carbon (%)
458	NA	NA	NA	0	NI	45	172	ND	ND	ND	ND	ND	ND	ND
458	NA	NA	NA	4	NI	18	86	ND	29	ND	12	29	ND	ND
459	NA	NA	NA	4.5	NI	10	21	ND	ND	ND	ND	ND	ND	ND
460	NA	NA	NA	4	NI	17	ND	ND	ND	ND	ND	ND	ND	ND
460B	10/14/93	1712042.18	1898974.99	0	NI	179	640	ND	ND	ND	ND	ND	ND	ND
460B	10/15/93	1712042.18	1898974.99	4	NI	10	ND	ND	ND	ND	ND	ND	ND	ND
461	NA	NA	NA	0	NI	197	2800	ND	13	ND	ND	13	ND	ND
461	NA	NA	NA	12.5	NI	90	ND	ND	11	ND	ND	11	ND	ND
461	NA	NA	NA	4.5	NI	118	154	ND	6	ND	ND	6	ND	ND
462C	10/14/93	1712060.58	1899192.2	0	NI	443	480	ND	ND	ND	ND	ND	ND	ND
462C	NA	NA	NA	4	NI	70	45	ND	ND	ND	ND	ND	ND	ND
463	NA	NA	NA	0	NI	5930	13000	ND	4	ND	75	79	ND	ND

Source: EMCON, 1994a.

NI=Matrix spikes out of control-matrix interference suspected.

Soil=Samples taken with split spoons.

bgs=Below ground surface.

NA=Not Available.

ND=Not Detected.

In 1992, petroleum product seepage from the Upper Naknek Site was reported to be entering the wetlands to the immediate south. SAIC (1993c) was contracted to install a french drain and lateral trench for product recovery. To date, insufficient product has been collected at the site for accurate analysis. Soil sampling at the Upper Naknek Site by SAIC did not significantly alter the area of contamination as defined by previous studies. High soil TRPH concentrations were detected over the interval from 0 to 10 feet bgs in the areas near MW-51 and MW-88. Total background lead concentrations were generally less than 10 mg/kg at the Upper Naknek Site, except in the area of product seeps, where lead is presumably derived from leaded fuels.

A more comprehensive soil characterization at the Upper Naknek Site was performed by EMCON in 1993 (EMCON, 1994a). Available results are shown in Table 2.3. Nine soil samples were collected from four soil borings. In addition, three sediment/surface water samples were collected. All samples were analyzed for VOCs, TRPH, DRO, metals, and inorganic parameters. One sample was analyzed for SVOCs. Figure 2.12 shows the areal extent of contamination, and Figure 2.13 shows the vertical extent of contamination at the site. The only VOCs detected in the soil and sediment samples were suspected to be from laboratory contaminants and included methylene chloride and acetone. However, a sample from soil boring 503 contained 51 µg/kg of ethylbenzene and 190 µg/kg of total xylenes. TRPHs were detected in soil borings 499, 500, 501, 502, 507, 509, and 510. The highest concentration was 9,200 mg/kg at a depth of 10 feet bgs from soil boring 499; however, the rest of the samples were below 2,000 mg/kg. Fifteen of eighteen soil samples exhibited DRO contamination, two of which exceeded 100 mg/kg at borings 499 (7,100 mg/kg at 10 feet bgs) and 502 (850 mg/kg at the surface). Boring 499 was located near the former bulk fuel storage area and indicates petroleum hydrocarbon contamination near the ground water surface. Soil boring 502 is located along the former aboveground pipeline and indicates surficial petroleum hydrocarbons.

Ten sediment samples collected in the wetland area below the Upper Naknek Site were collected to monitor fuel migration/contamination from the site. Five samples contained DROs in excess of 100 mg/kg and ranged between 138 and 895 mg/kg. The areal extent of DRO contamination is shown in Figure 2.12. One sample was analyzed for SVOCs. Several aromatic hydrocarbons and contaminants such as benzo(a)pyrene and di-n-butylphthalate were found above detection limits.

TABLE 2.3

SOIL ANALYTICAL DATA
SITE SS12
KING SALMON AIRPORT, ALASKA

Sample Location	Matrix	Sample Date	Northing	Easting	Sample Depth (feet)	Sample Type	Diesel (mg/kg)	TRPH (mg/kg)	Benzene (µg/kg)	Toluene (µg/kg)	Ethylbenzene (µg/kg)	Total Xylenes (µg/kg)	Total BTEX (µg/kg)	Total Phosphorus (mg/kg)	Total Organic Carbon (%)
499	Soil	10/20/93	NA	NA	0	NI	53	190	ND	ND	ND	ND	ND	ND	ND
499	Soil	10/20/93	NA	NA	5	NA	ND	32	ND	ND	ND	ND	ND	ND	ND
499	Soil	10/20/93	NA	NA	10	NI	7100	1200	ND	ND	ND	ND	ND	ND	ND
499	Soil	10/20/93	NA	NA	10	NA	ND	9200	ND	ND	ND	ND	ND	ND	ND
500	Soil	10/25/93	1714458.75	1889692.43	0	NI	12	27	ND	ND	ND	ND	ND	210	ND
500	Soil	10/25/93	1714458.75	1889692.43	0	NA	13	27	ND	ND	ND	ND	ND	ND	ND
500	Soil	10/25/93	1714458.75	1889692.43	5	NI	24	40	ND	ND	ND	ND	ND	ND	ND
500	Soil	10/25/93	1714458.75	1889692.43	10	NI	28	66	ND	ND	ND	ND	ND	ND	ND
501	Soil	10/25/93	1714452.63	1889943.23	0	NI	18	39	ND	ND	ND	ND	ND	ND	ND
501	Soil	10/25/93	1714452.63	1889943.23	5	NI	17	19	ND	ND	ND	ND	ND	150	ND
502	Soil	10/25/93	1714212.06	1890283.53	0	NI	850	350	ND	ND	ND	ND	ND	ND	ND
503	Sediment	10/24/93	NA	NA	0	NI	138	32	ND	ND	51	190	241	ND	ND
504	Sediment	10/24/93	NA	NA	0	NI	895	ND	ND	ND	ND	ND	ND	ND	ND
504	Sediment	10/24/93	NA	NA	0	NA	120	2300	ND	ND	ND	ND	ND	ND	ND
505	Sediment	10/24/93	NA	NA	0	NI	254	290	ND	ND	ND	ND	ND	ND	ND
505	Sediment	10/24/93	NA	NA	0	NA	222	1900	ND	ND	ND	ND	ND	ND	ND
507	Soil	10/24/93	1713467.68	1890061.57	0	NI	171	48	ND	ND	ND	ND	ND	ND	ND
508	Soil	10/24/93	1713493.57	1889952.16	0	NI	15	ND	ND	ND	ND	ND	ND	ND	ND
508	Soil	10/24/93	1713493.57	1889952.16	2	NI	11	ND	ND	ND	ND	ND	ND	ND	ND
509	Soil	10/24/93	1713602.09	1889905.93	0	NI	71	14	ND	ND	ND	ND	ND	ND	ND
509	Soil	10/24/93	1713602.09	1889905.93	2	NI	37	64	ND	ND	ND	ND	ND	ND	ND
510	Soil	10/24/93	1713608.03	1889508.34	0	NI	52	30	ND	ND	ND	ND	ND	ND	ND
510	Soil	10/24/93	NA	NA	5	NI	ND	ND	ND	ND	ND	ND	ND	270	0.09
512	Sediment	10/24/93	NA	NA	0	NI	22	15	ND	ND	ND	ND	ND	ND	ND
512	Sediment	10/24/93	NA	NA	0	NA	ND	110	ND	ND	ND	ND	ND	ND	ND
513	Sediment	10/24/93	NA	NA	0	NI	24	38	ND	ND	ND	ND	ND	ND	ND
513	Sediment	10/24/93	NA	NA	0	NA	11	ND	ND	ND	ND	ND	ND	ND	ND
514	Sediment	10/24/93	NA	NA	0	NI	25	31	ND	ND	ND	ND	ND	ND	ND

NI=Matrix spikes out of control-matrix interference suspected.

Soil=Samples take with split spoon.

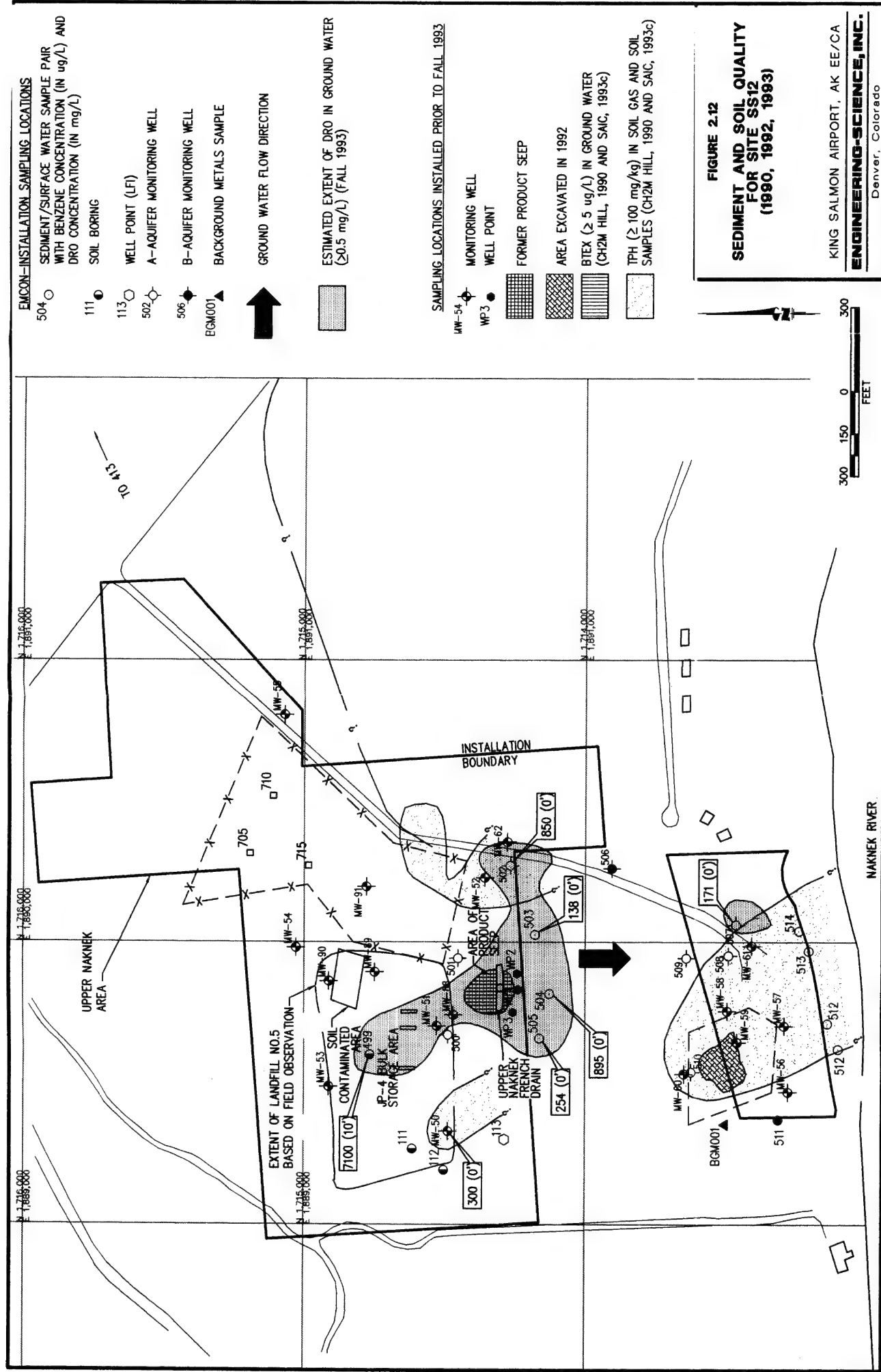
Sediment=Surface samples take via hand augers.

bgs=Below ground surface.

NA=Not available.

ND=Not detected.

Source: EMCON, 1994a.



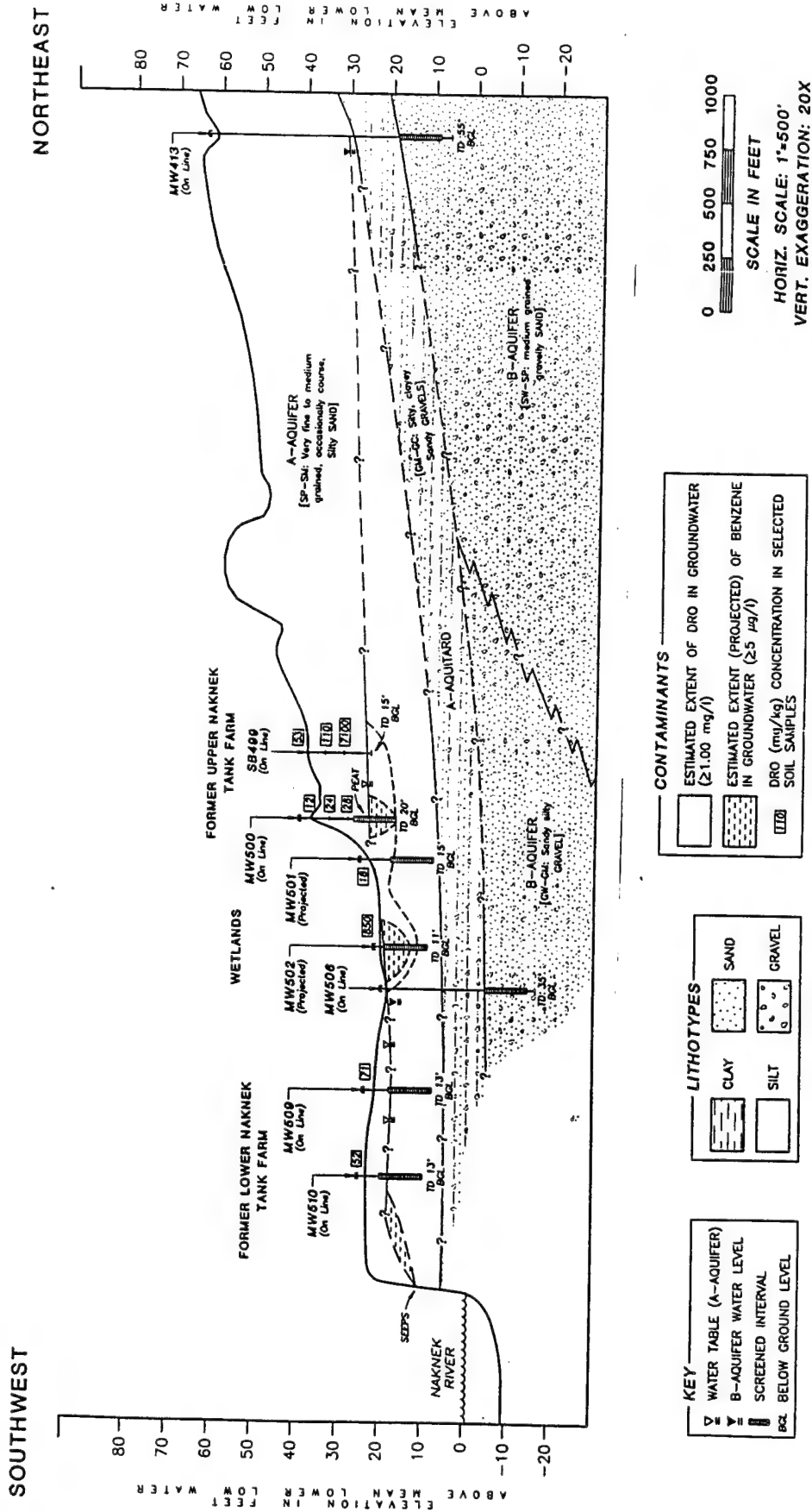


FIGURE 2.13

VERTICAL PROFILE OF SOIL CONTAMINATION SITE SS12

KING SALMON AIRPORT, AK EE/CA

ENGINEERING-SCIENCE, INC.

Denver, Colorado

SOURCE: EMCON, 1994a

M: \45011\DRAWINGS\94DN0862, 08/09/94 at 10:54

2.1.4 Ground Water and Surface Water Quality

2.1.4.1 Fire Training Area 1 (FT01)

Initial assessment of ground water quality performed in 1992 (SAIC, 1993a) identified DRO contamination in MW-92 and MW-95. MW-95 also contained TCE (390 µg/L), benzene (3,200 µg/L), toluene (7,200 µg/L), and total xylenes (4,300 µg/L). During field studies conducted in 1993, three ground water samples were collected from monitoring wells 460B, 462C, and 435, and analyzed for DROs, VOCs, SVOCs, and other inorganic parameters. VOCs were detected in ground water sample 435 at concentrations of 1,000 µg/L for benzene, 18 µg/L for toluene, and 640 µg/L for total xylenes. Only benzene appeared to exceed its state maximum contaminant level (MCL) at the site. DROs were detected in all three of the ground water samples at concentrations ranging from 202 µg/L in well 460 to 849 µg/L in well 435. DRO and VOC contamination in the ground water appears to be highest west and south of the fire training area; however, detectable levels of DROs and VOCs seem to be located throughout the site. Available ground water data are shown in Tables 2.4 and 2.5, respectively. Ground water sampling locations and data for Site FT01 are shown in Figure 2.14.

2.1.4.2 Upper Naknek Site (SS12)

Initial characterization of ground water quality at the Upper Naknek Site was determined by CH₂M Hill during a 1989 investigation (CH₂M Hill, 1990). Ground water samples collected from seven monitoring wells defined an area of benzene, toluene, and xylenes contamination centered on MW-51. The contamination was estimated to span a diameter of approximately 250 feet; concentrations of benzene in the water exceeded the State of Alaska drinking water MCL of 5 µg/L. Figure 2.15 illustrates the estimated area of BTEX contamination.

A ground water characterization study was performed by SAIC in 1992 (SAIC, 1992) for the surficial aquifer at the site. The ground water analysis confirmed previous results of benzene contamination. The ground water sample from MW-51 contained benzene (48 µg/L), toluene (640 µg/L), and total xylenes (576 µg/L). TRPH were also detected in ground water samples from wells MW-52 and MW-62 at 0.5 mg/L (the method detection

TABLE 2.4
GROUND WATER ANALYTICAL DATA
SITE FT01
KING SALMON AIRPORT, ALASKA

Sample Location	Sample Date	Northing	Easting	Disel Fuel (mg/L)	TPH (mg/L)	Benzene (µg/L)	Toluene (µg/L)	Ethylbenzene (µg/L)	Total Xylenes (µg/L)	Total BTEX (µg/L)	1,2,4-TMB (µg/L)	1,3,5-TMB (µg/L)	1,2,3-TMB (µg/L)
435	10/19/93	1711990.76	1898850.28	849	NA	1,000	18	99	640	1757	ND	ND	ND
460B	10/14/93	1712042.18	1898974.99	202	ND	ND	ND	ND	ND	ND	ND	ND	ND
462C	10/14/93	1712050.58	1899192.20	321	ND	ND	ND	ND	ND	ND	ND	ND	ND

ND=Not Detected

NA=Not Available

Source: EMCON, 1994a.

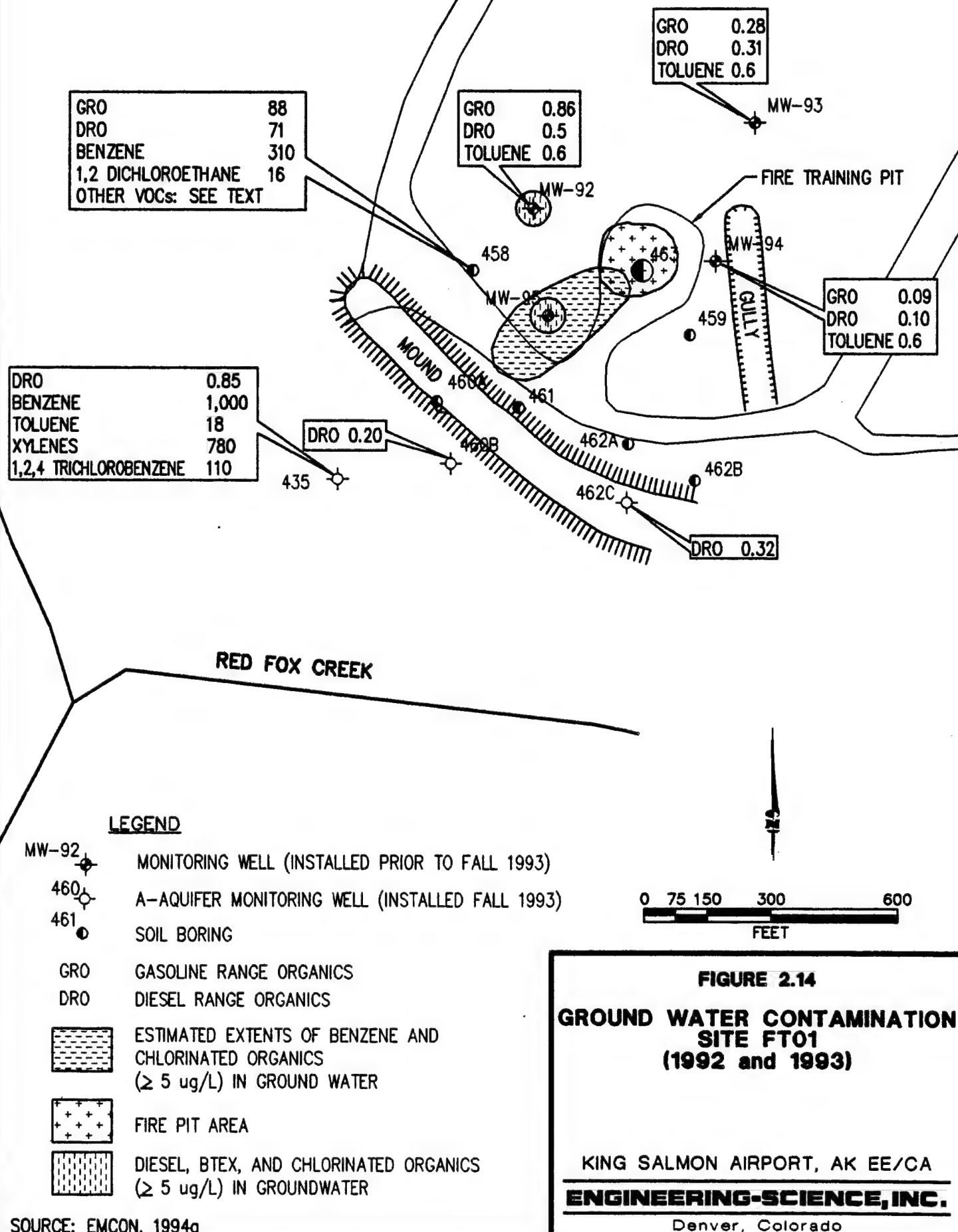
TABLE 2.5
GROUND WATER GEOCHEMICAL DATA
SITE FT01
KING SALMON AIRPORT, ALASKA

Sample Location	Sample Date	Northing	Easting	TOC (mg/L)	Total Phosphorus (mg/L)	Chloride (mg/L)	Sulfate (mg/L)	Nitrate (mg/L)	Alkalinity CaCO3 (mg/L)
460B	10/14/93	1712042.18	1898974.99	ND	ND	4	2.6	0.4	52
462C	10/14/93	1712050.58	1899192.20	ND	ND	2.9	3.2	0.3	41

ND=Not Detected.

NA=Not Available.

Source: EMCON, 1994a.



SOURCE: EMCON, 1994a

EMCON-INSTALLATION SAMPLING LOCATIONS

- 504 ○ SEDIMENT/SURFACE WATER SAMPLE PAIR WITH BENZENE CONCENTRATION (IN ug/L) DRO CONCENTRATION (IN mg/L)
- 111 ● SOIL BORING
- 113 ○ WELL POINT (LFI)
- 502 ○ A-AQUIFER MONITORING WELL WITH BENZENE CONCENTRATION (IN ug/L) DRO CONCENTRATION (IN mg/L)
- 506 ● B-AQUIFER MONITORING WELL
- BGM001 ▲ BACKGROUND METALS SAMPLE
- ESTIMATED EXTENT OF DRO IN GROUND WATER (>0.5 mg/L) (FALL 1993)
- TPH (>100 mg/kg) IN SOIL GAS AND SOIL SAMPLES (CH2M HILL, 1990 AND SAC, 1993)
- GROUND WATER FLOW DIRECTION

SAMPLING LOCATIONS INSTALLED PRIOR TO FALL 1993

- MW-54 ○ MONITORING WELL
- WP3 ● WELL POINT
- FORMER PRODUCT SEEP
- BETX (> 5 ug/L) IN GROUND WATER (CH2M HILL, 1990 AND SAC, 1993c)
- AREA EXCAVATED IN 1992

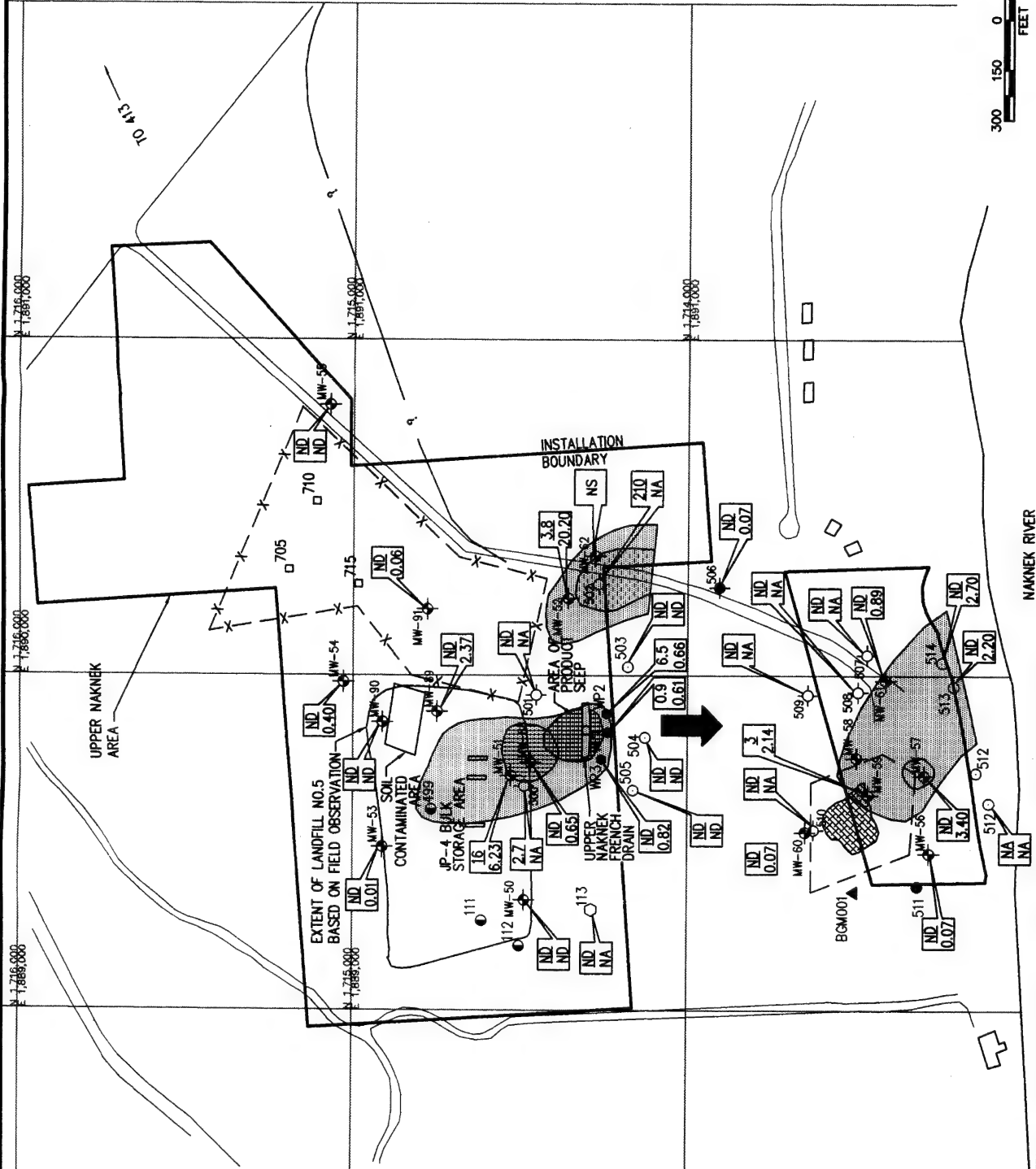
FIGURE 2.15

GROUND WATER CONTAMINATION SITE SS12 (1990, 1992, 1993)

KING SALMON AIRPORT, AK EE/CA

ENGINEERING-SCIENCE, INC.

Denver, Colorado



limit). Benzene was above Alaska's drinking water MCL of 5 µg/L in wells MW-51, MW-52, MW-62, and WP-2. Floating product was not reported during any of the water quality measurements.

Ground water samples were taken from 13 monitoring wells (data for 11 wells shown) and from three additional wells completed by EMCON in 1993 (EMCON, 1994a). Available EMCON data for Site SS12 are shown in Tables 2.6. through 2.9. All samples were analyzed for TRPH, VOCs, and inorganic parameters including chloride, sulfate, and alkalinity. VOCs detected in the samples were primarily from petroleum hydrocarbon contamination; however, several wells contained chlorinated organics. Locations of measured BTEX and DRO concentrations are shown in Figure 2.15. The results indicate that two ground water plumes present at the site exceed Alaska drinking water MCLs of 5 µg/L. The first plume is centered around well MW-51 and extends to a minimum of 100 feet in diameter. The plume is upgradient of the former product seep and the french drain. The second plume is located around monitoring well 502 and extends downgradient (south) for possibly 350 feet or more. The second plume had a recorded maximum total BTEX concentration of 2,900 µg/L. Geochemical analyses indicated that no TOC, total phosphorous, or nitrate were present in the ground water. Chloride concentrations were found to range from 3.2 to 7.0 mg/L and sulfate concentrations vary from 0.7 to 12.0 mg/L. Alkalinity varies from 21 to 128 mg/L (Table 2.7).

DRO were detected in 10 of the 13 ground water samples analyzed. The highest detected concentration in the easternmost identified plume was 3.8 mg/L at monitoring well MW-52. Figure 2.15 shows the areas where DRO concentrations were greater than 1 mg/L. The westernmost plume centers around MW-51 and extends north and south from the well as much as 300 feet further. This plume intersects and surrounds the area of the former product seep and the current french drain.

Surface water samples were also collected from 6 locations in 1993 (EMCON, 1993a). Only 504 showed significant concentrations of total BTEX (243.8 µg/L). TRPH levels of less than 1 mg/L were identified in well 504, 505, and 513. DRO in wells 513 and 514 were found to be 2.2 mg/L and 2.7 mg/L, respectively (Table 2.8). Geochemical analysis of the surface water indicates that TOC levels range from 0 to 26.1 mg/L. Chloride concentrations range from 0 to 5.2 mg/L and sulfate concentrations vary from 0 to 0.9 mg/L. Alkalinity in the surface water varies from 29 to 186 mg/L (Table 2.9).

TABLE 2.6

**GROUND WATER ANALYTICAL DATA
SITE SS12
KING SALMON AIRPORT, ALASKA**

Sample Location	Sample Date	Northing	Easting	Diesel Fuel (mg/L)	TPH (mg/L)	Benzene (µg/L)	Toluene (µg/L)	Ethylbenzene (µg/L)	Total Xylenes (µg/L)	Total BTEX (µg/L)	1,2,4-TMB (µg/L)	1,3,5-TMB (µg/L)	1,2,3-TMB (µg/L)
500	10/25/93	1714458.75	1889692.43	ND	39	2.7	3.1	36	ND	ND	100	9	ND
500	10/25/93	1714458.75	1889692.43	ND	ND	1.6	3	28	180	212.6	100	ND	ND
500	10/25/93	1714458.75	1889692.43	11	18	2.3	2.4	28	180	212.7	120	85	ND
501	10/25/93	1714452.63	1889943.23	ND	ND	1.6	3.5	28	180	213.1	100	ND	ND
502	10/25/93	1714212.06	1890283.53	ND	ND	210	11	370	2300	221	28	20	ND
506	11/9/93	1713907.68	1890261.42	0.069	ND	ND	3	ND	ND	3	ND	ND	ND
507	10/24/93	1713467.68	1890061.57	ND	ND	ND	ND	ND	2	2	ND	ND	ND
508	10/24/93	1713493.57	1889952.16	ND	ND	ND	0.6	ND	ND	0.6	ND	ND	ND
509	10/24/93	1713602.09	1889905.93	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
510	10/24/93	1713608.03	1889508.34	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
MW-50	10/93	1714488.00	1889331.00	16	NA	6.23	NA	NA	NA	NA	NA	NA	NA
MW-51	10/93	1714472.00	1889776.00	2.7	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-52	10/93	1714359.00	1890230.00	3.8	NA	20.2	NA	NA	NA	NA	NA	NA	NA
MW-53	10/93	1714912.00	1889489.00	ND	NA	0.01	NA	NA	NA	NA	NA	NA	NA
MW-54	10/93	ND	ND	ND	NA	0.4	NA	NA	NA	NA	NA	NA	NA
MW-55	10/93	19050.50	28764.00	ND	NA	ND	NA	NA	NA	NA	NA	NA	NA
MW-56	10/93	17670.00	27014.50	ND	NA	0.07	NA	NA	NA	NA	NA	NA	NA
MW-57	10/93	17913.00	27036.50	ND	NA	3.4	NA	NA	NA	NA	NA	NA	NA
MW-58	10/93	17962.00	27232.00	3	NA	2.14	NA	NA	NA	NA	NA	NA	NA
MW-61	10/93	18198.00	27142.50	ND	NA	0.89	NA	NA	NA	NA	NA	NA	NA
MW-88	10/93	1889849.00	1714469.00	ND	NA	0.65	NA	NA	NA	NA	NA	NA	NA
MW-89	10/93	1889895.00	1714749.00	ND	NA	2.37	NA	NA	NA	NA	NA	NA	NA
MW-90	10/93	1889863.00	1714912.00	ND	NA	ND	NA	NA	NA	NA	NA	NA	NA
MW-91	10/93	1890198.00	1714779.00	ND	NA	0.06	NA	NA	NA	NA	NA	NA	NA

Source: EMCON, 1994a.

ND=Not Detected.

NA=Not Available.

ml/w=Mean lower low water.

TABLE 2.7

**GROUND WATER GEOCHEMICAL DATA
SITE SS12
KING SALMON AIRPORT, ALASKA**

Sample Location	Sample Date	Northing	Easting	TOC (mg/L)	Total Phosphorus (mg/L)	Chloride (mg/L)	Sulfate (mg/L)	Nitrate (mg/L)	Alkalinity CaCO ₃ (mg/L)
501	10/25/93	1714452.63	1889943.23	ND	ND	7	2.2	ND	48
502	10/25/93	1714212.06	1890283.53	ND	ND	4	1.5	ND	128
506	11/9/93	1713907.68	1890261.42	ND	ND	4.3	12	ND	49
507	10/24/93	1713467.68	1890061.57	ND	ND	3.5	3.9	ND	29
508	10/24/93	1713493.57	1889952.16	ND	ND	3.2	1.7	ND	21
509	10/24/93	1713602.09	1889905.93	ND	ND	3.2	1.6	ND	21
510	10/24/93	1713608.03	1889508.34	ND	ND	4.3	0.7	ND	ND

ND=Not Detected.

NA=Not Available.

Source: EMCON, 1994a.

TABLE 2.8

SURFACE WATER ANALYTICAL DATA

SITE SS12

KING SALMON AIRPORT, ALASKA

Sample Location	Sample Date	Sample Type	Diesel Fuel (mg/L)	TRPH (mg/L)	Benzene (µg/L)	Toluene (µg/L)	Ethylbenzene (µg/L)	Total Xylenes (µg/L)	Total BTEX (µg/L)	1,2,4-TMB (µg/L)	1,3,5-TMB (µg/L)	1,2,3-TMB (µg/L)
503	10/24/93	N1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
504	10/24/93	N1	ND	0.3	ND	2.8	51	190	243.8	ND	ND	ND
505	10/24/93	FR1	ND	0.6	ND	ND	ND	ND	ND	ND	ND	ND
505	10/24/93	N1	ND	0.6	ND	ND	ND	ND	ND	ND	ND	ND
512	10/24/93	N1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
512	10/24/93	N1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
513	10/24/93	FR1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
513	10/24/93	N1	2.2	0.5	ND	ND	ND	ND	ND	5	ND	ND
514	10/24/93	N1	2.7	ND	ND	ND	ND	ND	ND	ND	ND	ND

ND=Not Detected.

N1=Matrix spikes out of control-matrix interference suspected.

Source: EMCON, 1994a.

TABLE 2.9
SURFACE WATER GEOCHEMICAL DATA
SITE SS12
KING SALMON AIRPORT, ALASKA

Sample Location	Sample Date	TOC (mg/L)	Total Phosphorus (mg/L)	Chloride (mg/L)	Sulfate (mg/L)	Alkalinity CaCO3 (mg/L)
503	10/24/93	14	1.3	4.9	0.4	186
504	10/24/93	23.8	0.05	4.4	ND	37
505	10/24/93	26.1	0.44	5.2	0.2	ND
512	10/24/93	ND	ND	ND	ND	29
513	10/24/93	12.6	18	3.9	0.8	91
514	10/24/93	7.5	0.02	3.6	0.9	42

ND=Not Detected.

Source: EMCON, 1994a.

NA=Not Available.

2.2 DEVELOPMENT OF CONCEPTUAL MODEL

A conceptual model is a three-dimensional representation of the hydrogeologic system at a site based on available geological, hydrological, climatological, and geochemical data. The purpose of the conceptual model is to integrate available data to produce a coherent representation of the ground water flow system. For the KSA sites, the conceptual models will also be used to aid in locating additional data collection points and to help develop the Bioplume II® model.

Successful conceptual model development involves:

- Definition of the problem to be solved;
- Model selection;
- Design of the conceptual model;
- Integration of available data, including;
 - Local geological and topographic data
 - Hydraulic data
 - Site stratigraphy
 - Contaminant concentration and distribution data; and
- Determination of additional data requirements.

2.2.1 Conceptual Model Design Components

Conceptual model components presented in the following sections are based on available data and will be expanded and modified as additional data are collected.

2.2.1.1 Fire Training Area No. 1 (FT01)

Site hydrogeologic data were integrated to produce hydrogeologic cross-sections that show the two- and three-dimensional relationships between hydrostratigraphic units (i.e., conductive units and aquitards) and the ground water system at the site. Figure 2.2 depicts the locations of two hydrogeologic sections. Figure 2.3 presents hydrogeologic sections A-A' and C-C'. Section A-A' is oriented in a northwest-southeast direction and is roughly parallel to ground water flow. Section C-C' is oriented in a north-south

direction and is roughly perpendicular to ground water flow. Figure 2.4 depicts ground water surface contours prepared using October 1993 ground water elevation data.

The surficial aquifer in the area appears to have little heterogeneity, and the water table resides in very-fine- to medium-grained silty sands. There is no evidence of significant seasonal variation in the direction of horizontal ground water flow, and there is no current documentation of silty or fine-grained units that may locally create confined conditions in the aquifer. Detectable levels of contamination appear to extend as far as 10 feet bgs at different site locations. A distinct residual-phase zone or ground water contaminant plume has not been delineated at this time; additional data collected as part of the field effort will help refine the conceptual model. Given the available data, ES will model this site as an unconfined sand or sand and silt aquifer. This conceptual model will be modified as necessary as additional site hydrogeologic data become available.

Based on the size of the contaminant plume and the potential migration distance, it is likely that a 20 by 30 model grid will be used. The size and number of grid cells will be adjusted as site conditions and preliminary runs of the Bioplume II® model dictate.

If free-phase product is discovered at the site, it may be necessary to use the fuel-water partitioning model of Bruce et al. (1991) to provide a conservative source term to model the partitioning of BTEX compounds from the free product phase into the ground water. In order to use this model, samples of product must be collected and analyzed for mass fraction of BTEX compounds.

2.2.1.2 Upper Naknek (SS12)

Available hydrogeologic data for this site are summarized in the cross-section prepared by EMCON (1994a) and shown on Figure 2.7. Contaminant distribution data for the ground water (Figure 2.15) indicate two distinct plumes of dissolved-phase hydrocarbons at the upper Naknek area. Vertical profiles of recorded soil contamination at the site (Figure 2.13) imply that contamination exists close to the ground surface in both soil and ground water, as wetlands conditions exist. Free product has not been detected.

Instead of attempting to characterize and model conditions in the vicinity of both plumes, this study will focus on the western plume emanating from the area comprising

the JP-4 bulk storage area. This plume was chosen because it has significant areal extent and has been characterized in the most detail, thereby facilitating plume delineation and documentation of potential natural attenuation mechanisms. Conclusions reached from the investigation of the western plume may apply to the eastern plume as well.

Given the available data, ES will model this site as an unconfined aquifer comprised of fine- to coarse-grained sand. This conceptual model will be modified as necessary as additional site hydrogeologic data become available.

Based on the size of the contaminant plumes and the potential migration distances, it is likely that a 20 by 30 model grid will be used for the model. The size and number of grid cells will be adjusted as site conditions and preliminary runs of the Bioplume II® model dictate.

Because free product was discovered at the southern end of the Upper Naknek Site, it is likely that it will be necessary to use the fuel-water partitioning model of Bruce et al. (1991) to provide a conservative source term to model the partitioning of BTEX compounds from the free-product phase into the ground water. In order to use this model, samples of free product must be collected and analyzed for mass fraction of BTEX compounds.

2.2.2 Potential Pathways and Receptors

Potential preferential contaminant migration pathways such as subsurface utility corridors will be identified during the field work phase of this project. Such information can be obtained from KSA maps which delineate such utility corridors. Potential human and/or ecological receptors of petroleum hydrocarbon-contaminated ground water will also be identified. Pathways to potential receptors may include discharge of contaminated ground water into downgradient wetlands or surface water bodies, discharge of contaminated ground water to the ground surface, and migration of the contaminant plume into downgradient potable and nonpotable water wells. This study will be confined to the A-Aquifer at and downgradient of Sites SS12 and FT01.

Ground water extraction wells installed by the USAF at KSA are all screened in the C-Aquifer (approximately 200 ft bgs) and are unlikely to be affected by contamination from either site FT01 or SS12. As noted before, previous studies have indicated that there are

two aquitards separating the C-Aquifer from the surficial aquifer. Private wells off USAF property and in the town of King Salmon are predominantly screened in the B-Aquifer. A greater risk of ground water contamination exists for the B-Aquifer from downward migration of contamination breaching the A-Aquitard barrier. Downward migration may not be a potential problem in all areas because the potentiometric surface of the B-Aquifer has been recorded as nearly equivalent to the A-Aquifer in many locations, which suggests a minimal or nonexistent vertical hydraulic gradient from the A-Aquifer to the B-Aquifer.

Ground water at Site FT01 may ultimately discharge into Red Fox Creek. Ground water contamination was detected within 500 feet of the creek at the time of the most recent data collection event in 1993 (EMCON, 1994a). No interception trench or other remedial strategy exists at the Site FT01 at this time.

Ground water at the Upper Naknek Site may ultimately discharge into the Naknek River, which is approximately 1,000 feet south of the western hydrocarbon plume. Potential contamination also exists in the wetland area separating the Upper Naknek from the Lower Naknek Site. Ground water contours suggest that contaminants will migrate in the direction of the Naknek River. A french drain has been installed on the downgradient side of fuel contamination in an effort to inhibit further downgradient migration of contaminants.

SECTION 3

COLLECTION OF ADDITIONAL DATA

To adequately complete the EE/CA and to demonstrate that natural attenuation of site contaminants is occurring at sites FT01 and SS12, additional site-specific hydrogeologic data will be collected. The physical and chemical hydrogeologic characteristics listed below will be determined during the field work phase of the EE/CA.

Physical hydrogeologic characteristics to be determined include:

- Depth from measurement datum to the potentiometric surface;
- Depth from measurement datum to the base of the shallow saturated zone (where feasible);
- Location of potential ground water recharge and discharge areas;
- Hydraulic conductivity, through slug tests;
- Dispersivity (estimated);
- Detailed stratigraphic analysis of subsurface media; and
- Determination of extent and thickness of free product;

Chemical hydrogeologic characteristics to be determined include:

- Dissolved oxygen concentration;
- Temperature;
- Specific conductance;
- pH;
- Chemical analysis of free product to determine mass fraction BTEX; and
- Chemical analysis of ground water and soil for parameters listed in Table 3.1.

To obtain these data, additional drilling, soil and ground water sampling, and aquifer testing will be performed.

TABLE 3.1
ANALYTICAL PROTOCOL FOR
GROUND WATER AND SOIL
KING SALMON AIRPORT, ALASKA

MATRIX	METHOD	FIELD (F) OR ANALYTICAL LABORATORY (L)
WATER		
Total Iron	Colorimetric, HACH Method 8008	F
Ferrous Iron (Fe+2)	Colorimetric, HACH Method 8146	F
Ferric Iron (Fe+3)	Difference between total and ferrous iron	F
Manganese	Colorimetric, HACH Method 8034	F
Sulfate	Colorimetric, HACH Method 8051	F
Nitrate	Titrimetric, HACH Method 8039	F
Nitrite	Titrimetric, HACH Method 8507	F
Redox Potential	A2580B, direct reading meter	F
Oxygen	HACH 16046 DO Meter	F
pH	E150.1/SW9040, direct reading meter	F
Conductivity	E120.1/SW9050, direct reading meter	F
Temperature	E170.1	F
Carbon Dioxide	Titrimetric, HACH Method 1436-01	F
Alkalinity (Carbonate [CO ₃ -2] and Bicarbonate [HCO ₃ -1])	Titrimetric, HACH Method 8221	F
Nitrate	E300 or SW9056	L
Nitrite	E300 or SW9056	L
Chloride	E300 or SW9056	L
Sulfate	E300 or SW9056	L
Methane	Gas Chromatography	L
Dissolved Organic Carbon	A5310C	L
Aromatic Hydrocarbons	SW8020	L
Total Hydrocarbons	SW8015, modified	L
SOIL		
Total Organic Carbon	Method 415.1	L
Moisture	ASTM D-2216	L
Aromatic Hydrocarbons	SW8020	L
Total Hydrocarbons	SW8015, modified	L

The following sections describe the procedures that will be followed when collecting additional site-specific data. Drilling, soil sampling, lithologic logging, and monitoring well development procedures are described in Section 3.1. Ground water sampling procedures are described in Section 3.2. Aquifer testing procedures are described in Section 3.3.

3.1 DRILLING, SOIL SAMPLING, AND MONITORING WELL INSTALLATION

To further characterize the hydrogeologic conditions of the shallow subsurface for Bioplume II[®] model development, up to 12 new ground water monitoring wells at Site FT01 and 12 new ground water monitoring wells at SS12 will be installed. An allowance for an extra well at each site will be made. In addition, wells will be placed in six nested pairs so that the vertical extent of ground water contamination can be better defined. The following sections describe the proposed well locations and completion intervals, equipment decontamination procedures, drilling and soil sampling, monitoring well installation, well development, and well location and datum surveying.

3.1.1 Well Locations and Completion Intervals

New monitoring wells will be installed at each site in order to collect information on soil and ground water conditions. Site conditions dictate the use of a truck mounted drilling rig, portable-percussion drilling device, or hand auger to install wells at Sites FT01 and SS12.

3.1.1.1 Fire Training Area No. 1 (FT01)

Up to 12 new wells (with an option for one additional well) will be installed to further characterize the nature and extent of ground water contamination at the site. The new monitoring wells will be installed as six nests of two wells each to provide information on vertical gradients and distribution of contaminants and other geochemical parameters. Well locations were selected to provide the hydrogeologic data necessary for successful implementation of the Bioplume II[®] model. Figure 3.1 shows the proposed well locations, and Table 3.2 contains proposed completion details. All nested wells will be installed with 5-foot screens, with the shallow well screened across the water table and

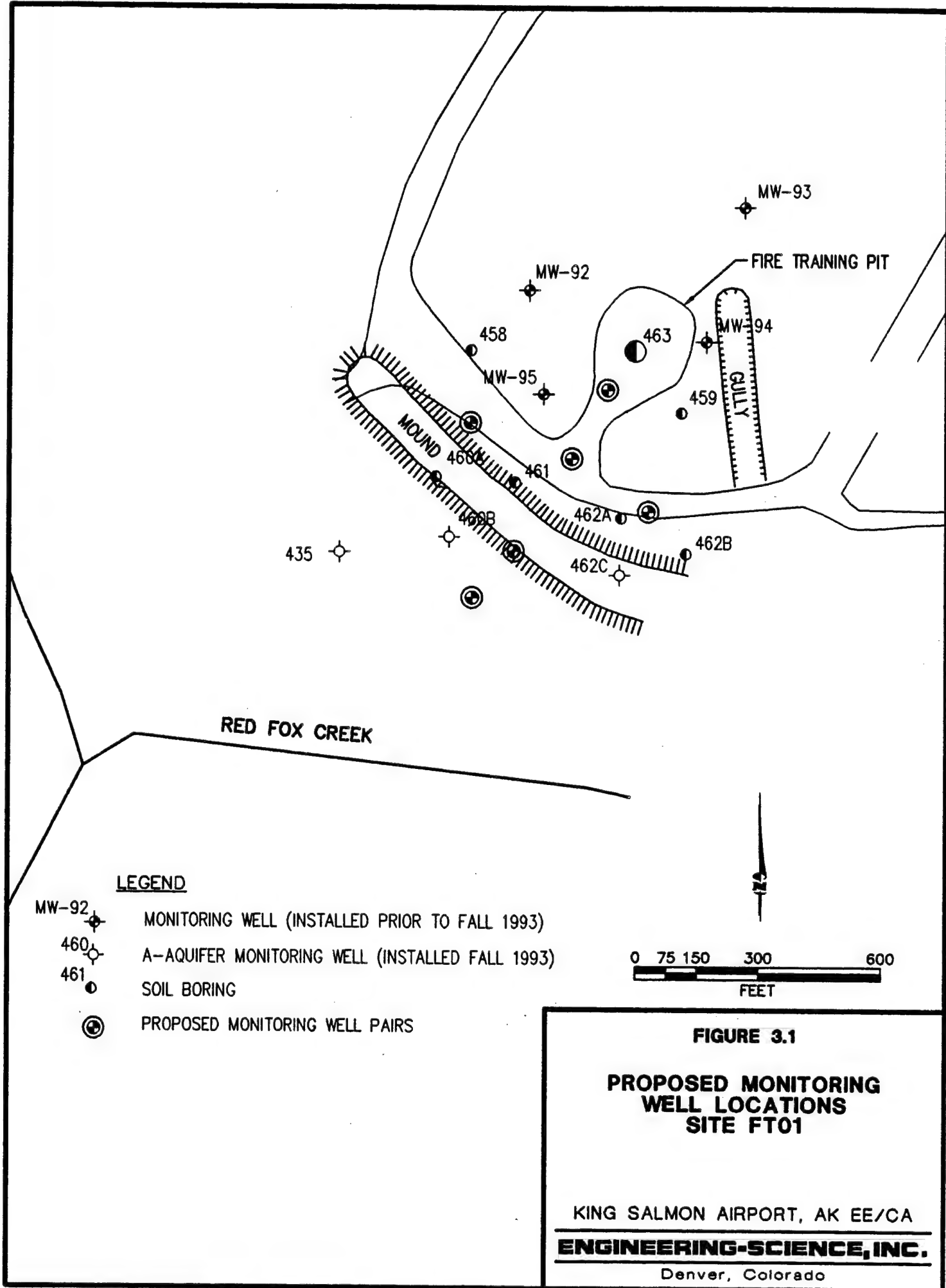


TABLE 3.2

**PROPOSED MONITORING WELL SPECIFICATIONS
SITE FT01
KING SALMON AIRPORT, ALASKA**

PROPOSED WELL LOCATION	PROPOSED WELL NUMBER	ESTIMATED DEPTH TO WATER (ft)	TOTAL DEPTH (ft)*	NEST OR SINGLE?	DEPTH TO SCREEN TOP (ft) BASE (ft)	SCREEN LENGTH (ft)	DEPTH TO BENTONITE SEAL TOP (ft) BASE (ft)
150 feet southwest of center of fire training pit	ESMW-1S	14	19	nest	14 19	5	11 13
	ESMW-1D		34		29 34	5	26 28
300 feet southwest of center of fire training pit	ESMW-2S	14	19	nest	14 19	5	11 13
	ESMW-2D		34		29 34	5	26 28
500 feet southwest of center of fire training pit	ESMW-3S	14	19	nest	14 19	5	11 13
	ESMW-3D		34		29 34	5	26 28
700 feet southwest of center of fire training pit	ESMW-4S	14	20	nest	15 20	5	12 14
	ESMW-4D		35		30 35	5	27 29
200 feet west/southwest of MW-95	ESMW-5S	14	19	nest	14 19	5	11 13
	ESMW-5D		34		29 34	5	26 28
75 feet northeast of soil bore 462A	ESMW-6S	14	19	nest	14 19	5	11 13
	ESMW-6D		34		29 34	5	26 28
*Estimated							

the deep well screened 10 to 15 feet below the water table. Well completion depths are expected to range between approximately 15 and 35 feet bgs.

3.1.1.2 Upper Naknek Site (SS12)

Up to 12 wells (with an option for one additional well) will be installed at the Upper Naknek Site. Twelve of the new wells will be installed as six nests of two wells each to provide information on vertical gradients and vertical distribution of contaminants. Well locations were selected to provide hydrogeologic data necessary for successful implementation of the Bioplume II[®] model. Figure 3.2 shows the proposed well locations, and Table 3.3 contains proposed completion details. All nested wells will be installed with 5-foot screens, with the shallow well screened across the water table and the deep well screened 10 to 15 feet below the shallow well. Well completion depths are expected to range between 6 and 35 feet bgs.

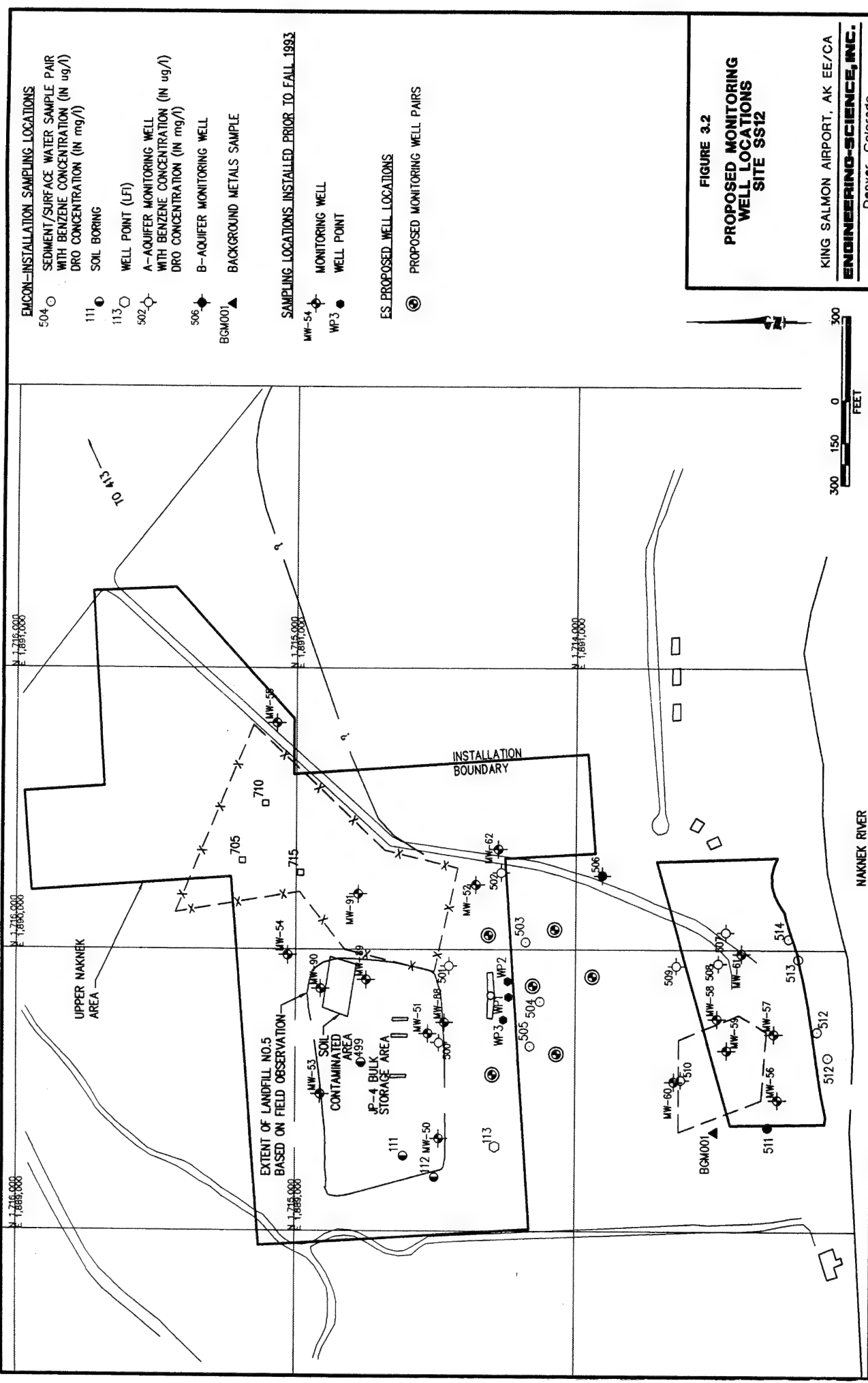
3.1.2 Well Drilling and Installation Procedures

This subsection addresses the procedures for drilling and installing new monitoring wells. All new monitoring wells will be installed in accordance with general procedures outlined in Section 8.5 of *A Compendium of Superfund Field Methods* (USEPA, 1987).

3.1.2.1 Pre-Drilling Activities

All necessary digging, drilling, and ground water monitoring well installation permits will be obtained prior to mobilizing to the field. In addition, all utility lines will be located and proposed drilling locations will be cleared prior to any drilling activities. Personnel from KSA will be responsible for these actions.

Water to be used in drilling, equipment cleaning, or grouting will be obtained from one of the KSA onsite water supplies. Water use approval will be verified with the appropriate facility personnel. Only potable water will be used for the activities listed above. The field hydrogeologist will make the final determination as to the suitability of site water for these activities.



EMCON-INSTALLATION SAMPLING LOCATIONS

- 504 ○ SEDIMENT/SURFACE WATER SAMPLE PAIR WITH BENZENE CONCENTRATION (IN ug/l)
- 111 ● SOIL BORING
- 113 ○ WELL POINT (LFT)
- 502 ○ A-AQUIFER MONITORING WELL WITH BENZENE CONCENTRATION (IN ug/l)
- 506 ● B-AQUIFER MONITORING WELL
- BGM001 ▲ BACKGROUND METALS SAMPLE

SAMPLING LOCATIONS INSTALLED PRIOR TO FALL 1993

- MW-54 ● MONITORING WELL
- WP3 ● WELL POINT

ES PROPOSED WELL LOCATIONS

- ⊙ PROPOSED MONITORING WELL PAIRS

FIGURE 3.2

**PROPOSED MONITORING WELL LOCATIONS
SITE SS12**

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TABLE 3.3

PROPOSED MONITORING WELL SPECIFICATIONS
SITE SSI2
KING SALMON AIRPORT, ALASKA

PROPOSED WELL LOCATION	PROPOSED WELL NUMBER	ESTIMATED DEPTH TO WATER (ft)	TOTAL DEPTH (ft)*	NEST OR SINGLE?	DEPTH TO SCREEN TOP (ft)	DEPTH TO SCREEN BASE (ft)**	SCREEN LENGTH (ft)	DEPTH TO BENTONITE SEAL TOP (ft)	DEPTH TO BENTONITE SEAL BASE (ft)
200 feet west of the french drain	ESMW-8S	4	8	nest	3	8	5	0	2
	ESMW-8D		23		18	23	5	15	17
150 feet south of the midpoint of the french drain	ESMW-9S	2	6	nest	1	6	5	0	1
150 feet east of the french drain	ESMW-9D		21		16	21	5	13	15
	ESMW-10S	4	8	nest	3	8	5	0	2
	ESMW-10D		23		18	23	5	15	17
250 feet south/southwest of WP3	ESMW-11S	2	6	nest	1	6	5	0	1
	ESMW-11D		21		16	21	5	13	15
300 feet south of WP2	ESMW-12S	2	6	nest	1	6	5	0	1
	ESMW-12D		21		16	21	5	13	15
300 feet southeast of WP2	ESMW-13S	2	6	nest	1	6	5	0	1
	ESMW-13D		21		16	21	5	13	15
*Estimated									
** Top of A-Aquitard is approximately 15 to 20 feet bgs at this site and may alter drilling depths of deep monitoring wells.									

3.1.2.2 Equipment Decontamination Procedures

Prior to arriving at the site, and between each drilling site, the drill rig, augers, drilling rods, bits, casing, samplers, tools, and other downhole equipment will be decontaminated using a high-pressure, steam/hot water wash. Only potable water will be used for decontamination.

During drilling operations, the drill rig, augers, and any downhole drilling and/or sampling equipment will be decontaminated at a KSA decontamination pad or another location specified by KSA personnel. Water from the decontamination operations at decontamination pads will be allowed to collect in the decontamination pad collection tanks. Precautions will be taken to minimize any impact to the area surrounding the decontamination pad that might result from the decontamination operations.

All soil sampling tools will be cleaned onsite prior to use and between each sampling event with a clean water/phosphate-free detergent mix and a clean water rinse. All well completion materials that are not factory-sealed will be cleaned onsite prior to use with a high-pressure, steam/hot water wash using approved water. Materials that cannot be cleaned to the satisfaction of the field hydrogeologist will not be used. All decontamination activities must be conducted in a manner so that the excess water will be controlled and not allowed to flow into any open borehole.

If contaminated soils are encountered during drilling [based on visual, olfactory, or photoionization (PID) indications, and the potential for cross-contamination is anticipated, drilling will be stopped and modified drilling procedures will be implemented to prevent the transfer of contaminants to deeper water-bearing strata.

Fuel, lubricants, and other similar substances will be handled in a manner consistent with accepted safety procedures and standard operating practices. Well completion materials will not be stored near or in areas which could be affected by these substances.

Surface runoff such as miscellaneous spills and leaks, precipitation, and spilled drilling fluid will not be allowed to enter any boring or well either during or after drilling/well construction. To prevent this from happening, starter casing, recirculation tanks, berms around the borehole, and surficial bentonite packs, as appropriate, will be used.

3.1.2.3 Drilling and Soil Sampling

Drilling in unconsolidated soils will be accomplished using the hollow-stem auger method. Borings will be drilled and continuously sampled to the proposed total depth of the monitoring well. In the case of nested well pairs, only the borehole of the deep well will be sampled and logged. A final borehole diameter of at least 8 inches will be required for the installation of wells with a 2-inch inside-diameter (ID) casing. Auger ID will not be less than 4 inches.

If subsurface conditions are such that the planned drilling technique does not produce acceptable results (e.g., unstable borehole walls or poor soil sample recovery), another technique deemed more appropriate for the type of soils present will be used. Any alternate soil sampling procedure used must be approved by the ES field hydrogeologist and must be appropriate for the subsurface lithologies present at the site.

Continuous soil samples will be obtained using a CME® split-barrel continuous sampling device or another similar method judged acceptable by the ES field hydrogeologist. Samples will be collected continuously over the full depth of the soil borehole unless an alternative sampling frequency is requested by the ES field hydrogeologist. Procedures will be modified, if necessary, to ensure good sample recovery. The soil samples collected will be removed from the continuous sampler and placed on clean aluminum foil for logging.

A portion of the soil sample will be placed in a clean container for PID headspace VOC measurements. Representative portions of the soil samples collected for the headspace procedure will be quickly transferred to the containers, which will be sealed and held for 15 minutes at an ambient temperature of 65 °F or greater. Semiquantitative measurements will be made by puncturing the container seal with the PID probe and reading the concentration of the headspace gases. The PID relates the concentration of total VOCs in the sample to an isobutylene calibration standard. It is anticipated that headspace measurements will be performed on all samples collected during the drilling operations. The PID will also be used to monitor the worker breathing zone.

The ES field hydrogeologist will be responsible for observing all drilling and well installation activities, maintaining a detailed descriptive log of subsurface materials recovered, photographing representative samples, and properly labeling and storing samples.

An example of the proposed geologic boring log form is presented as Figure 3.3. The descriptive log will contain:

- Sample interval (top and bottom depth);
- Sample recovery;
- Presence or absence of contamination;
- Soil or rock description, including: relative density, color, major textural constituents, minor constituents, porosity, relative moisture content, plasticity of fines, cohesiveness, grain size, structure or stratification, relative permeability, and any other significant observations; and
- Lithologic contacts: the depth of lithologic contacts and/or significant textural changes measured and recorded to the nearest 0.1 foot.

Soils exhibiting petroleum hydrocarbon contamination based on PID screening will be drummed and stored onsite during the drilling operations. Upon completion of the drilling activities, two composite samples from the contaminated soil drums will be collected and analyzed by USEPA Methods SW8020 and SW8015 (modified). Upon receipt of the soil analytical results, soil disposal will be coordinated by KSA personnel. Clean soil will be handled by KSA personnel, who will be responsible for the soil's final disposition.

3.1.2.4 Borehole Abandonment

Any boring not completed as a monitoring well will be abandoned by backfilling with bentonite chips or a cement/sodium bentonite grout mixture to within approximately 3 feet of ground surface. If cement/sodium bentonite grout is used, the bentonite content of the grout will not exceed 8 percent by dry weight. If standing water is present in the boring, the grout mixture will be placed using a tremie pipe placed below the static water level near the bottom of the boring. The grout mixture will be pumped through the tremie pipe until undiluted grout is present in the boring near ground surface.

Twenty-four hours after abandonment, the field hydrogeologist or designate will check the abandoned site for grout settlement and specify additional grout, or backfill the hole to ground surface with clean, native soil or concrete, as necessary.

GEOLOGIC BORING LOG

Sheet 1 of 1

BORING NO.: _____ CONTRACTOR: _____ DATE SPUD: _____
 CLIENT: AFCEE RIG TYPE: _____ DATE CMPL: _____
 JOB NO.: 722450.11 DRLG METHOD: _____ ELEVATION: _____
 LOCATION: KING SALMON AIRPORT BORING DIA.: _____ TEMP: _____
 GEOLOGIST: _____ DRLG FLUID: _____ WEATHER: _____
 COMENTS: _____

Elev (ft)	Depth (ft)	Pro- file	US CS	Geologic Description	Sample		Penet Res	PID(ppm)	TLV(ppm)	TOTAL BTEX(ppm)	TPH (ppm)
					No.	Depth (ft)					
	- 1 -										
	- 5 -										
	- 10 -										
	- 15 -										
	- 20 -										
	- 25 -										
	- 30 -										
	- 35 -										

NOTES

bgs - Below Ground Surface
 GS - Ground Surface
 TOC - Top of Casing
 NS - Not Sampled
 SAA - Same As Above

SAMPLE TYPE

D - DRIVE
 C - CORE
 G - GRAB



Water level drilled

FIGURE 3.3

GEOLOGIC BORING LOG

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Denver, Colorado

3.1.2.5 Monitoring Well Installation

Ground water monitoring wells will be installed in all soil borings. Wells at each site will be completed with aboveground protective casings, and constructed to minimize damage caused by frost heave. Detailed well installation procedures are described in the following paragraphs.

3.1.2.5.1 Well Materials Decontamination

Well completion materials will be inspected by the field hydrogeologist and determined to be clean and acceptable for use. If not factory sealed, casing, screen and casing plugs and caps will be cleaned before use with a high-pressure, steam/hot water cleaner using approved water. Prepackaged sand, bentonite, and cement will be used in well construction, and the bags will be inspected for possible external contamination before use. Materials that cannot be cleaned to the satisfaction of the field hydrogeologist will not be used.

3.1.2.5.2 Well Casing

Upon completion of drilling to the proper boring termination depth, a monitoring well will be installed. Well construction details will be noted on the Monitoring Well Installation Record form as shown in Figure 3.4. This information will become part of the permanent field record for the site.

Blank well casing will be constructed of Schedule 40 polyvinyl chloride (PVC) with an ID of 2 inches. All well casing sections will be flush-threaded; glued joints will not be used. The casing at each well will be fitted with a threaded bottom plug and a top cap constructed of the same type of material as the well casing. The top cap will be vented to maintain ambient atmospheric pressure within the well casing.

The field hydrogeologist will verify and record the boring depth, the lengths of all casing sections, and the depth to the top of all well completion materials placed in the annulus between the casing and borehole wall. All lengths and depths will be measured to the nearest 0.1 foot.

MONITORING WELL INSTALLATION RECORD

JOB NAME KING SALMON AIRPORT WELL NUMBER _____
 JOB NUMBER 722450.11 INSTALLATION DATE _____ LOCATION _____
 DATUM ELEVATION _____ GROUND SURFACE ELEVATION _____
 DATUM FOR WATER LEVEL MEASUREMENT _____
 SCREEN DIAMETER & MATERIAL _____ SLOT SIZE _____
 RISER DIAMETER & MATERIAL _____ BOREHOLE DIAMETER _____
 GRANULAR BACKFILL MATERIAL _____ ES REPRESENTATIVE _____
 DRILLING METHOD HOLLOW STEM AUGER DRILLING CONTRACTOR _____

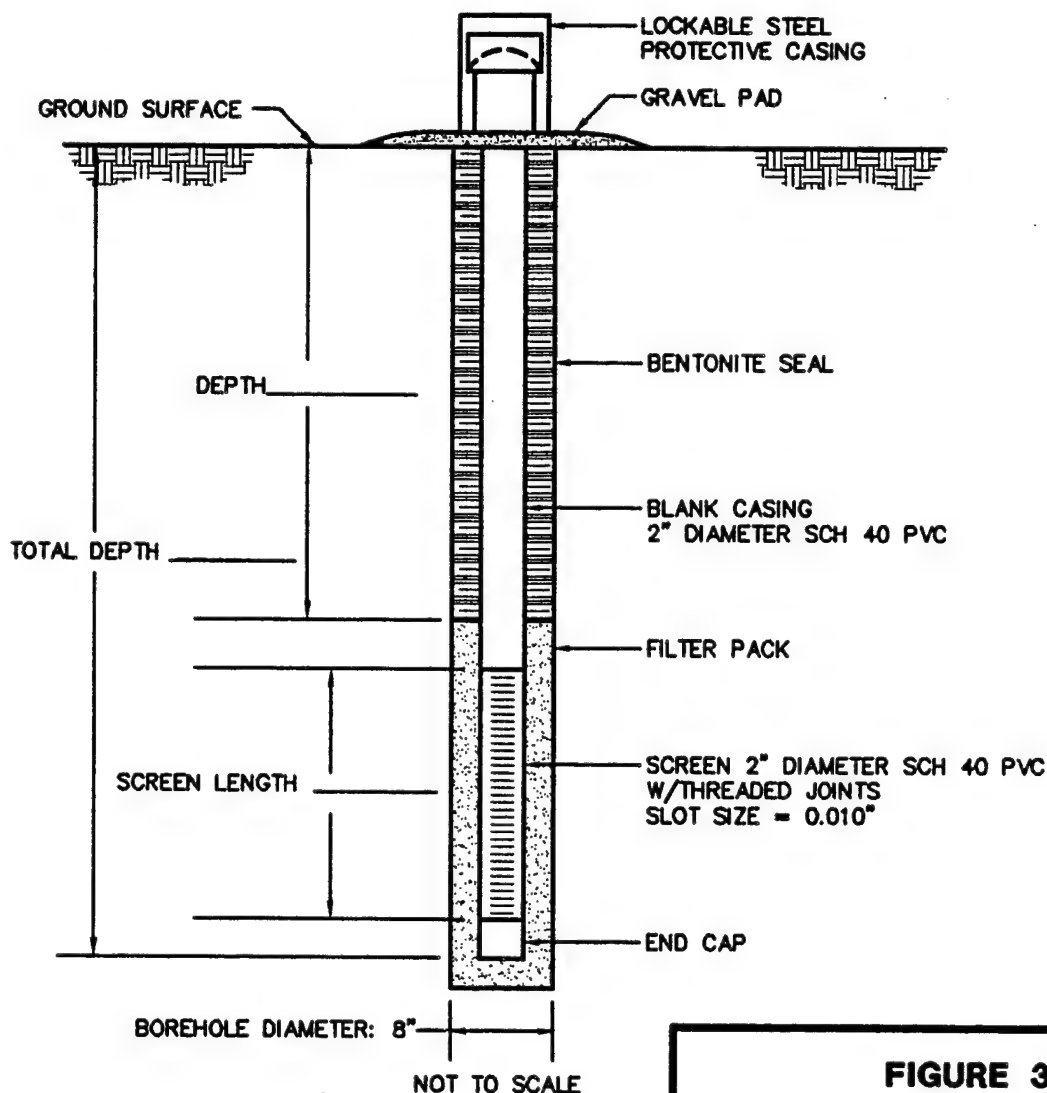


FIGURE 3.4

MONITORING WELL INSTALLATION RECORD

STABILIZED WATER LEVEL _____ FEET
 BELOW DATUM.
 TOTAL WELL DEPTH _____ FEET
 BELOW DATUM.
 MEASURED ON _____

KING SALMON AIRPORT, AK EE/CA
ENGINEERING-SCIENCE, INC.
 Denver, Colorado

3.1.2.5.3 Well Screen

Well screens will be constructed of flush-threaded, Schedule 40 PVC with an ID of 2 inches. Screens will be factory-slotted with 0.010-inch openings. The position of the screen will be selected by the field hydrogeologist after consideration is given to the geometry and hydraulic characteristics of the stratum in which the well will be screened.

3.1.2.5.4 Sand Filter Pack

A graded sand filter will be placed around the screened interval and will extend at least 2 feet above the top of the screen. The sand filter will consist of 10-20 silica sand.

3.1.2.5.5 Annular Sealant

Wells completed at Sites FT01 or SS12 will require annular sealant different than concrete because frost may be a problem at the site. Instead of using a bentonite/cement grout, a bentonite seal is placed along the entire length of the annulus from the filter pack to the ground surface. The bentonite seal may be a bentonite slurry or hydrated bentonite chips. Use of such a seal reduces frost heave damage potential because bentonite remains plastic at low temperatures, and thus minimizes shear between the annular seal and the surrounding earth. Pure sodium bentonite has a permeability low enough to provide a sufficient borehole seal.

After the bentonite seal is emplaced, it will be allowed to settle for approximately 24 hours. Any settling will be topped off with bentonite pellets hydrated with potable water. The bentonite will be topped off with sand to minimize dehydration of the bentonite, and a gravel mat will be placed over the sand to prevent damage to the surface of the seal.

If the bentonite annular seal described above is not deemed appropriate by KSA personnel, a minimum 2-foot thick bentonite seal will be placed above the filter pack using sodium bentonite pellets. The bentonite pellet seal will be overlain by a cement/sodium bentonite grout that will extend from the top of the pellet seal to approximately 1 foot bgs. The cement/sodium bentonite grout will consist of one 94-pound sack of cement and about 5 pounds of bentonite for each 7 gallons of water used. The bentonite content of the cement/bentonite will not exceed 8 percent by dry weight. The grout will be overlain by concrete that will extend to the ground surface. To reduce heaving of the newly installed monitoring well caused by freeze-thaw processes and to support the protective casing, it is imperative that the uppermost concrete seal extend to

at least 1 foot bgs to contact the cement/sodium bentonite grout and have an 8" thick ring around the outer circumference of the well casing.

3.1.2.5.6 Protective Covers

Monitoring wells at sites FT01 and SS12 will be completed above the ground surface using a 5-foot section of 6-inch-diameter steel pipe with a locking cap. This pipe will be placed into the gravel and bentonite around the aboveground PVC piping. In conjunction with the modified annular seal, this design allows the steel casing to float independently of the PVC casing, preventing damage to the PVC resulting from movement of the steel casing.

If requested by KSA personnel, monitoring wells will be completed with an at-grade (flush-mounted) protective cover. If pavement is present, the at-grade cover will be cemented in place using concrete blended to the existing pavement. In areas where pavement is not present, a 6-inch-thick, 2-foot-diameter concrete pad will be constructed around the protective cover. In either case, the concrete immediately surrounding the well cover will be sloped gently away from the protective casing to facilitate runoff during precipitation events. Construction details for both well completion methods are presented schematically on Figures 3.5 and 3.6.

3.1.2.6 Well Development

Before any new well can be considered to be in proper condition for monitoring water levels or taking water samples, it must be developed. Development involves removing sediment from inside the well casing and flushing, fines, cuttings, and drilling fluids from the sand pack and the portion of the formation adjacent to the well screen.

Well development will be accomplished using dedicated disposable bailers. The bailer will be regularly lowered to the bottom of the well so that fines which have accumulated in the bottom are agitated and removed from the well in the development water.

Development will be continued until a minimum of 10 casing volumes of water have been removed from the well and the water pH, temperature, and specific conductivity have stabilized. If the development water remains turbid after removal of 10 casing

volumes, development will be continued until the water becomes clear or the turbidity of the water produced has been stable after the removal of several casing volumes.

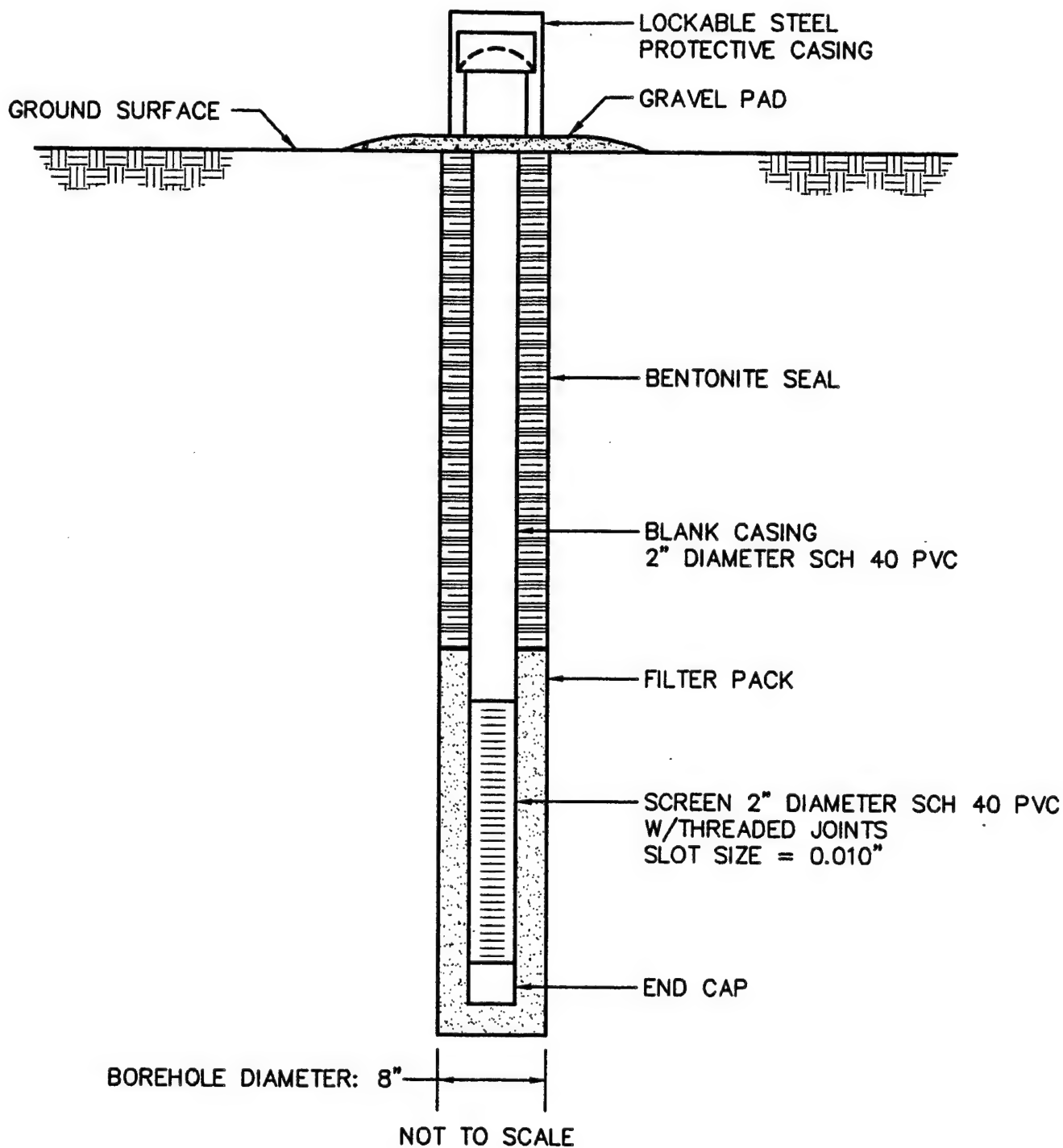


FIGURE 3.5

TYPICAL FROST HEAVE
WELL DESIGN

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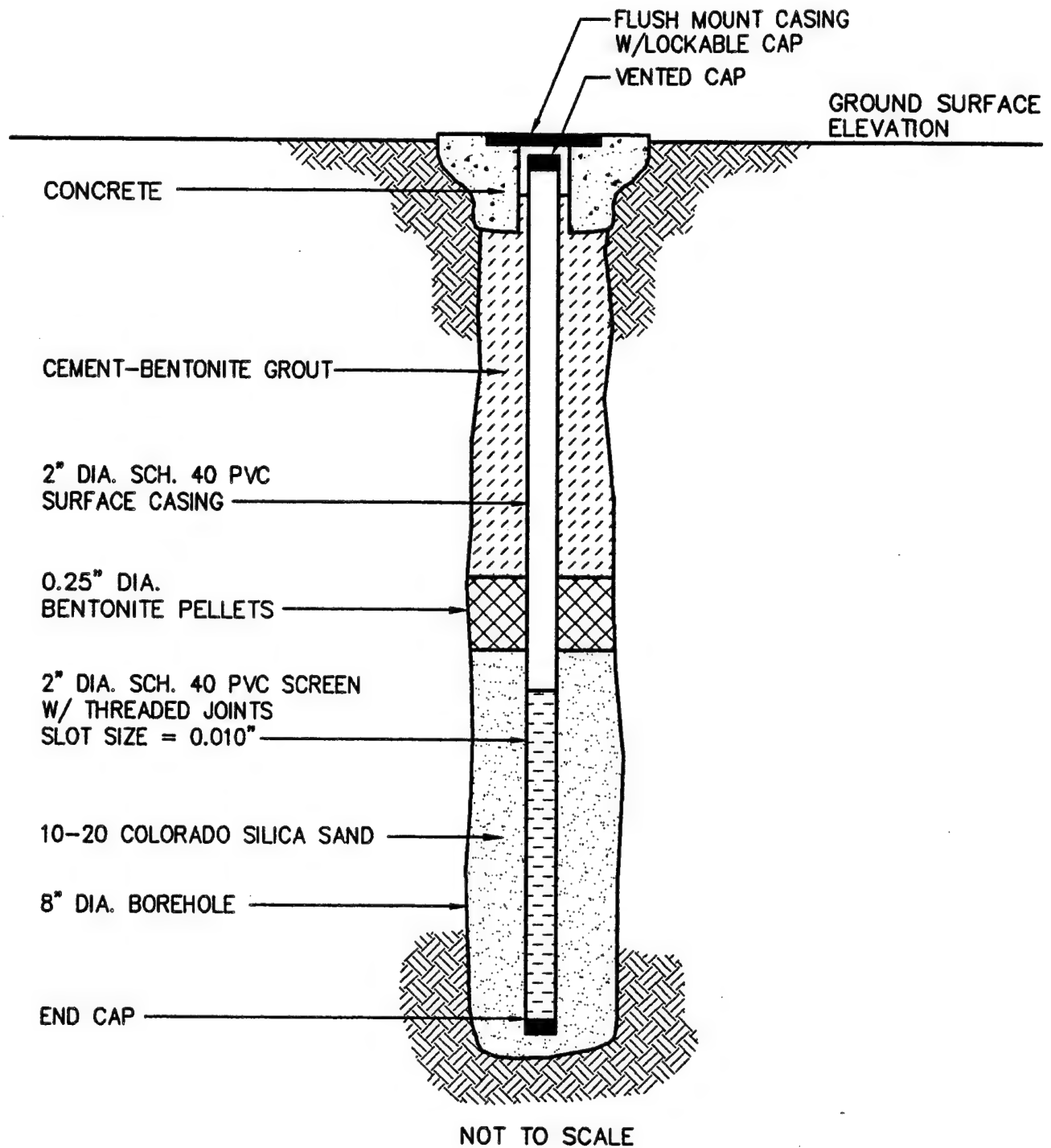


FIGURE 3.6

**TYPICAL MONITORING WELL
COMPLETION DIAGRAM**

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Denver, Colorado

The development procedure specifies that 10 casing volumes of water be removed from the well. However, some wells completed in marginal aquifers will go dry during well development prior to the recovery of 10 casing volumes. In these low-productivity wells, development activity may have to be staged over a period of time to allow water to refill the well bore. In the event 10 casing volumes of water cannot be recovered, the water volume recovered and the deficiency will be noted in the development records.

Clean development waters will be discharged at the drilling site in a manner to control excessive ponding. Waters that are contaminated (visibly or as indicated by PID readings) will be collected in 55-gallon drums and stored at the site. Transport and disposal of stored wastes at an on-site air stripper will be the responsibility of base personnel.

3.1.2.7 Well Development Records

A record of well development will be maintained by the field hydrogeologist for each well in a bound field notebook. Figure 3.7 is an example of the well development record. A summary well development record form will be prepared for each well and submitted with the EE/CA report. Development records will include:

- Well number;
- Date and time of development;
- Development method;
- Pre-development water level and well depth;
- Volume of water produced;
- Description of water produced;
- Post-development water level and well depth; and
- Field analytical measurements, including pH and specific conductivity.

3.1.2.8 Water Level Measurements

Water levels at the monitoring wells will be measured within a short time interval so that the data are comparable. Water levels in the wells will not be measured until they are developed and the water level has stabilized. The depth to water below the measurement datum will be made using an electric water level probe to the nearest 0.01 ft. In wells

Figure 3.7
MONITORING WELL DEVELOPMENT RECORD

Page__ of__

Job Number: _____
Location _____
Well Number _____

Job Name: _____
By _____ Date _____
Measurement Datum _____

Pre-Development Information

Time (Start): _____

Water Level: _____

Total Depth of Well: _____

Water Characteristics

Color _____ Clear Cloudy
Odor: None Weak Moderate Strong
Any Films or Immiscible Material _____
pH _____ Temperature(°F °C) _____
Specific Conductance(μS/cm) _____

Interim Water Characteristics

Gallons Removed _____

pH _____

Temperature (°F °C) _____

Specific Conductance(μS/cm) _____

Post-Development Information

Time (Finish): _____

Water Level: _____

Total Depth of Well: _____

Approximate Volume Removed: _____

Water Characteristics

Color _____ Clear Cloudy
Odor: None Weak Moderate Strong
Any Films or Immiscible Material _____
pH _____ Temperature(°F °C) _____
Specific Conductance(μS/cm) _____

Comments: _____

where free product may be encountered, an oil/water interface probe will be used to measure the depths to product and water. In addition, water level measurements will be made in all previously existing monitoring wells at the site.

3.1.2.9 Well Location and Datum Survey

The location and elevation of the new wells will be surveyed by a registered surveyor soon after well completion. Horizontal locations will be measured relative to established KSA coordinates. Horizontal coordinates will be measured to the nearest 0.01 foot. Vertical location of the ground surface adjacent to the well casing, the measurement datum (top of the interior casing), and the top of the outer well casing will be measured relative to a US Geological Survey mean sea level datum. The ground surface elevation will be measured to the nearest 0.1 foot and the measurement datum, outer casing, and surveyor's pin (if present) elevation will be measured to the nearest 0.01 foot.

3.1.3 Site Restoration

After well installation and sampling are complete, each well site will be restored as close to its original condition as possible. Clean drill cuttings brought to the surface will be placed in 55-gallon drums for disposal by KSA personnel. Visibly contaminated cuttings will be placed in 55-gallon drums, and two composite samples will be collected and analyzed as described in Section 3.1.2.3. These drums will be stored onsite pending results of the soil analytical testing. Proper disposal of cuttings will be coordinated by KSA personnel. Contaminated (as indicated by PID screening or visual evidence) development waters and sampling purge waters will be stored in 55-gallon drums and transported to the KSA water treatment facility for treatment.

3.2 GROUND WATER SAMPLING

This section describes the scope of work required for collecting ground water quality samples. After completion of well installation and development activities, new wells and existing wells will be sampled using dedicated bailers. All water samples collected from ground water monitoring wells will be obtained using dedicated, disposable bailers. To maintain a high degree of quality control during this sampling event, the procedures described in the following sections will be followed.

Ground water sampling will be conducted by qualified scientists and technicians trained in the conduct of well sampling, records documentation, and chain-of-custody procedures. In addition, sampling personnel will have thoroughly reviewed this plan prior to sample acquisition and will have a copy of the plan available onsite for reference. Ground water sampling is described in Section 3.2.3.

Activities that will occur during ground water sampling are summarized below:

- Assembly and preparation of equipment and supplies;
- Inspection of the well integrity, including:
 - Protective cover, cap, and lock,
 - External surface seal and pad,
 - Well stick-up, cap, and datum reference,
 - Internal surface seal,
 - Condition of bladder pump if present;
- Ground water sampling, including:
 - Water-level measurements,
 - Visual inspection of borehole water,
 - Well casing evacuation,
 - Sampling;
- Sample preservation and shipment, including:
 - Sample preparation,
 - Onsite measurement of physical parameters,
 - Sample labeling;
- Completion of sampling records;
- Completion of chain-of-custody records; and
- Sample disposition.

Detailed ground water sampling and sample handling procedures are presented in following sections.

3.2.1 Ground Water Sampling Locations

Ground water samples will be collected from existing and newly installed monitoring wells at each site using dedicated disposable bailers.

3.2.1.1 Monitoring Well Sampling Locations

3.2.1.1.1 Site FT01

Approximately 12 new monitoring wells will be installed at locations documented in Section 3.1.1.1. After completion of well installation and development activities, these wells and seven previously existing wells will be sampled using dedicated bailers. The existing wells to be sampled include MW-92, MW-93, MW-94, MW-95, 435, 460B, and 462C.

3.2.1.1.2 Site SS12

Approximately 12 new monitoring wells will be installed in locations documented in Section 3.1.1.2. After completion of well installation and development activities, these wells and 13 previously existing wells will be sampled using dedicated bailers. The existing wells to be sampled include MW-50, MW-51, MW-52, MW-53, MW-90, MW-89, MW-88, 500, 501, WP1, WP2, WP3, and 113.

3.2.2 Preparation for Sampling

All equipment to be used for sampling will be assembled and properly cleaned and calibrated (if required) prior to arriving in the field. In addition, all recordkeeping materials will be gathered prior to leaving the office.

3.2.2.1 Equipment Cleaning

All portions of sampling and test equipment that will contact the sample will be thoroughly cleaned before each use. This includes water level probe and cable, lifting line, test equipment for onsite use, and other equipment or portions thereof which will contact the samples. Based on the types of sample analyses to be conducted, the following cleaning protocol will be used:

- Clean with potable water and phosphate-free laboratory detergent;
- Rinse with potable water;
- Rinse with distilled or deionized water;
- Rinse with reagent-grade methanol; and
- Air dry the equipment prior to use.

Any deviations from these procedures will be documented in the field scientist's field notebook and on the ground water sampling form (Figure 3.8).

If precleaned dedicated sampling equipment is used, the cleaning protocol specified above will not be required. USEPA Mobile Laboratory-supplied sample containers will be cleaned and sealed by the laboratory and therefore will not need to be cleaned in the field. The type of container provided and the method of container decontamination will be in the USEPA Mobile Laboratory's permanent record of the sampling event.

3.2.2.2 Equipment Calibration

As required, field analytical equipment will be calibrated according to the manufacturer's specifications prior to field use. This applies to equipment used for onsite chemical measurements such as pH, electrical conductivity, and temperature.

3.2.3 Sampling Procedures

Special care will be taken to prevent contamination of the ground water and extracted samples. The two primary ways in which sample contamination can occur are through contact with improperly cleaned equipment and by cross-contamination through insufficient cleaning of equipment between wells. To prevent such contamination, the water level probe and cable used to determine static water levels and well total depth will be thoroughly cleaned before and after field use and between uses at different sampling locations according to the procedures presented in Section 3.2.2.1. In addition to the use of properly cleaned equipment, a clean pair of new, disposable nitrile gloves will be worn each time a different well is sampled.

The following paragraphs present the procedures that comprise ground water sample acquisition from both newly installed and previously existing ground water monitoring wells. These activities will be performed in the same order as presented below. Exceptions to this procedure will be noted in the field scientist's field notebook.

Figure 3.8
Ground Water
Sampling Record

SAMPLING LOCATION _____
SAMPLING DATE(S) _____

GROUND WATER SAMPLING RECORD - MONITORING WELL _____
(number)

REASON FOR SAMPLING: ☐ Regular Sampling; ☐ Special Sampling;

DATE AND TIME OF SAMPLING: _____, 19____ a.m./p.m.

SAMPLE COLLECTED BY: _____ of _____

WEATHER: _____

DATUM FOR WATER DEPTH MEASUREMENT (Describe): _____

MONITORING WELL CONDITION:

☐ LOCKED:

☐ UNLOCKED

WELL NUMBER (IS - IS NOT) APPARENT

STEEL CASING CONDITION IS: _____

INNER PVC CASING CONDITION IS: _____

WATER DEPTH MEASUREMENT DATUM (IS - IS NOT) APPARENT

☐ DEFICIENCIES CORRECTED BY SAMPLE COLLECTOR

☐ MONITORING WELL REQUIRED REPAIR (describe): _____

Check-off

1 ☐ EQUIPMENT CLEANED BEFORE USE WITH _____
Items Cleaned (List): _____

2 ☐ PRODUCT DEPTH _____ FT. BELOW DATUM
Measured with: _____

WATER DEPTH _____ FT. BELOW DATUM
Measured with: _____

3 ☐ WATER CONDITION BEFORE WELL EVACUATION (Describe):
Appearance: _____
Odor: _____
Other Comments: _____

4 ☐ WELL EVACUATION:
Method: _____
Volume Removed: _____
Observations: Water (slightly - very) cloudy
Water level (rose - fell - no change)
Water odors: _____
Other comments: _____

Figure 3.8 (Cont'd)
Ground Water Sampling Record

Ground Water Sampling Record - Monitoring Well No. _____ (Cont'd)

5 [] SAMPLE EXTRACTION METHOD:

[] Bailer made of: _____
[] Pump, type: _____
[] Other, describe: _____

Sample obtained is [] GRAB [] COMPOSITE SAMPLE

6 [] ONSITE MEASUREMENTS:

Temp: _____ °	Measured with: _____
pH: _____	Measured with: _____
Conductivity: _____	Measured with: _____
Dissolved Oxygen: _____	Measured with: _____
Redox Potential: _____	Measured with: _____
Salinity: _____	Measured with: _____
Nitrate: _____	Measured with: _____
Sulfate: _____	Measured with: _____
Ferrous Iron: _____	Measured with: _____
Other: _____	

7 [] SAMPLE CONTAINERS (material, number, size): _____

8 [] ONSITE SAMPLE TREATMENT:

[] Filtration: Method _____ Containers: _____
 Method _____ Containers: _____
 Method _____ Containers: _____

[] Preservatives added:

 Method _____ Containers: _____
 Method _____ Containers: _____
 Method _____ Containers: _____
 Method _____ Containers: _____

9 [] CONTAINER HANDLING:

[] Container Sides Labeled
[] Container Lids Taped
[] Containers Placed in Ice Chest

10 [] OTHER COMMENTS: _____

3.2.3.1 Preparation of Location

Prior to starting the sampling procedure, the area around the well will be cleared of foreign materials, such as brush, rocks, and debris. These procedures will prevent sampling equipment from inadvertently contacting debris around the monitoring well.

3.2.3.2 Water-Level and Total Depth Measurements

Static water levels will be measured prior to removing any water from the well. An electrical water level probe will be used to measure the depth to ground water below the datum to the nearest 0.01 foot. If free product is known or suspected to be present, an oil/water interface probe will be used to measure the depths to product and the product/water interface. After measuring the static water level, the water level probe will be slowly lowered to the bottom of the well and the total well depth will be measured to the nearest 0.01 foot. Based on these measurements, the volume of water to be purged from the well can be calculated. Wells containing free product will not be purged.

3.2.3.3 Well Bore Purging

The volume of water contained within the well casing at the time of sampling will be calculated, and three times the calculated volume will be removed from the well. All purge water will be placed in 55-gallon drums for ultimate disposal at the air stripper located at KSA for treatment. Transport and disposal of the drums will be the responsibility of base personnel. The empty drums will be rinsed with hot water and returned to the appropriate owner. Dedicated disposable bailers will be used for well evacuation.

If a well is evacuated to a dry state during purging, the well will be allowed to recharge and the sample will be collected as soon as sufficient water is present in the well to obtain the necessary sample quantity. Sample compositing, or sampling over a lengthy period by accumulating small volumes of water at different times to eventually obtain a sample of sufficient volume, will not be allowed.

3.2.3.4 Sample Extraction

Dedicated, disposable, polyethylene bailers will be used to extract ground water samples from the well. The bailer will be lowered into the water gently to prevent

splashing and extracted gently to prevent creation of an excessive vacuum in the well. The sample will be transferred directly to the appropriate sample container. The water sample will be transferred from the bailer by discharging the sample from the bottom. The water should be carefully poured down the inner walls of the sample bottle to minimize aeration of the sample.

Unless other instructions are given by the analytical laboratory, sample containers will be completely filled so that no air space remains in the container. Excess water collected during sampling will be placed into the 55-gallon drums used for well purge waters and transported to the KSA airstripper by base personnel.

3.2.4 Onsite Chemical Parameter Measurement

The following sections describe the procedures to be used for field analysis of ground water samples from monitoring wells at the FT01 and SS12 sites. Methods also are summarized in Table 3.1.

3.2.4.1 Dissolved Oxygen Measurements

Except where the USEPA Mobile Laboratory can obtain dissolved oxygen (DO) measurements from collected ground water samples, DO measurements will be taken using a meter supplied by ES with a downhole oxygen sensor before and immediately following ground water sample acquisition. When DO measurements are taken in monitoring or sampling wells/points that have not yet been sampled, the existing monitoring wells/points will be purged until DO levels stabilize.

3.2.4.2 Reduction/Oxidation Potential

The reduction/oxidation (redox) potential of ground water is an indicator of the relative tendency of a solution to accept or transfer electrons. Redox reactions in ground water are usually biologically mediated and therefore, the redox potential of a ground water system depends upon and influences rates of biodegradation. Redox potential can be used to provide real-time data on the location of the contaminant plume, especially in areas undergoing anaerobic biodegradation. The redox potential of a ground water sample taken inside the contaminant plume should have a redox potential somewhat less than that taken in the upgradient location.

The redox potential of a ground water sample can change significantly within a short time following sample acquisition and exposure to atmospheric oxygen. As a result, this parameter will be measured in the field in unfiltered, unpreserved, "fresh" water collected by the same technique as the samples taken for laboratory analyses. The measurements will be made as quickly as possible in a clean glass container separate from those intended for laboratory analysis.

3.2.4.3 pH, Temperature, and Specific Conductance

Because the pH, temperature, and specific conductance of a ground water sample can change significantly within a short time following sample acquisition, these parameters will be measured in the field in unfiltered, unpreserved, "fresh" water collected by the same technique as the samples taken for laboratory analyses. The measurements will be made in a clean glass container separate from those intended for laboratory analysis, and the measured values will be recorded on the ground water sampling record (see Section 3.2.5.5).

3.3.4.3 Carbon Dioxide Measurements

Carbon dioxide concentrations in groundwater will be measured in the field by experienced ES scientists via titrimetric analysis using HACH® Method 8223 (0-250 mg/L as CO₂).

3.3.4.4 Alkalinity Measurements

Alkalinity in groundwater helps buffer the groundwater system against acids generated through both aerobic and anaerobic biodegradation processes. Alkalinity of the groundwater sample will be measured in the field by experienced ES scientists via titrimetric analysis using USEPA-approved HACH® Method 8221 (0-5000 mg/L as CaCO₃).

3.3.4.5 Nitrate- and Nitrite-Nitrogen Measurements

Nitrate-nitrogen concentrations are of interest because nitrate can act as an electron acceptor during hydrocarbon biodegradation under anaerobic soil or groundwater conditions. Nitrate-nitrogen is also a potential nitrogen source for biomass formation for hydrocarbon-

degrading bacteria. Nitrite-nitrogen is an intermediate byproduct in both ammonia nitrification and in nitrate reduction in anaerobic environments.

Nitrate- and nitrite-nitrogen concentrations in groundwater will be measured in the field by experienced ES scientists via colorimetric analysis using a HACH® DR/700 Portable Colorimeter. Nitrate concentrations in groundwater samples will be analyzed after preparation with HACH® Method 8039 (0-30.0 mg/L NO₃). Nitrite concentrations in groundwater samples will be analyzed after preparation with USEPA-approved HACH® Method 8507 (0-0.35 mg/L NO₂).

3.3.4.6 Sulfate and Sulfide Sulfur Measurements

Sulfate in groundwater is a potential electron acceptor for fuel-hydrocarbon biodegradation in anaerobic environments, and sulfide is resultant after sulfate reduction. The ES scientist will measure sulfate and sulfide concentrations via colorimetric analysis with a HACH® DR/700 Portable Colorimeter after appropriate sample preparation. USEPA-approved HACH® Methods 8051 (0-70.0 mg/L SO₄) and 8131 (0.60 mg/L S²⁻) will be used to prepare samples and analyze sulfate and sulfide concentrations, respectively.

3.3.4.7 Total Iron, Ferrous Iron, and Ferric Iron Measurements

Iron is an important trace nutrient for bacterial growth, and different states of iron can affect the oxidation/reduction potential of the groundwater and act as an electron acceptor for biological metabolism under anaerobic conditions. Iron concentrations will be measured in the field via colorimetric analysis with a HACH® DR/700 Portable Colorimeter after appropriate sample preparation. HACH® Method 8008 for total soluble iron (0-3.0 mg/L Fe³⁺ + Fe²⁺) and HACH® Method 8146 for ferrous iron (0-3.0 mg/L Fe²⁺) will be used to prepare and quantitate the samples. Ferric iron will be quantitated by subtracting ferrous iron levels from total iron levels.

3.3.4.8 Manganese Measurements

Manganese is a potential electron acceptor under anaerobic environments. Manganese concentrations will be quantitated in the field using colorimetric analysis with a HACH® DR/700 Portable Colorimeter. USEPA approved HACH® Method 8034 (0-20.0 mg/L) will be used to prepare the samples for quantitation of manganese concentrations.

3.2.5 Sample Handling

This section describes the handling of samples from the time of sampling until the samples arrive at the laboratory.

3.2.5.1 Sample Preservation

The USEPA Mobile Laboratory will add any necessary chemical preservatives prior to shipping the containers to the site. Samples will be properly prepared for transportation to the USEPA Laboratory by placing them in a cooler with ice to maintain a shipping temperature of 4 degrees centigrade (°C).

3.2.5.2 Sample Container and Labels

Sample containers and appropriate container lids will be provided by the USEPA Mobile Laboratory. The sample containers will be filled as described in Sections 3.1.2.3 and 3.2.3.4, and the container lids will be tightly closed. The sample label will be firmly attached to the container side, and the following information will be legibly and indelibly written on the label:

- Facility name;
- Sample identification;
- Sample type (ground water, surface water, etc.);
- Sampling date;
- Sampling time;
- Preservatives added; and
- Sample collector's initials.

3.2.5.3 Sample Shipment

After the samples are sealed and labeled, they will be packaged for transport to the USEPA Mobile Laboratory. The following packaging and labeling procedures will be followed:

- Package sample so that it will not leak, spill, or vaporize from its container; and
- Label shipping container with:
 - Sample collector's name, address, and telephone number;

- Laboratory's name, address, and telephone number;
- Description of sample;
- Quantity of sample; and
- Date of shipment.

The packaged samples will be delivered to the laboratory as soon as possible after sample acquisition.

3.2.5.4 Chain-of-Custody Control

After the samples have been collected, chain-of-custody procedures will be followed to establish a written record of sample handling and movement between the sampling site and the USEPA Mobile Laboratory. Each shipping container will have a chain-of-custody form completed in triplicate by the sampling personnel. One copy of this form will be kept by the sampling contractor after sample delivery to the analytical laboratory, and the other two copies will be retained at the laboratory. One of the laboratory copies will become a part of the permanent record for the sample and will be returned with the sample analytical results. The chain-of-custody will contain the following information:

- Sample identification number;
- Sample collector's printed name and signature;
- Date and time of collection;
- Place and address of collection;
- Sample matrix;
- Chemical preservatives added;
- Analyses requested;
- Signatures of individuals involved in the chain of possession; and
- Inclusive dates of possession.

The chain-of-custody documentation will be placed inside the shipping container so that it will be immediately apparent to the laboratory personnel receiving the container, but will not be damaged or lost during transport. The shipping container will be sealed so that it will be obvious if the seal has been tampered with or broken.

3.2.5.5 Sampling Records

In order to provide complete documentation of the sampling event, detailed records will be maintained by the field hydrogeologist. At a minimum, these records will include the following information:

- Sample location (facility name);
- Sample identification;
- Sample location map or detailed sketch;
- Date and time of sampling;
- Sampling method;
- Field observations of sample appearance and odor;
- Weather conditions;
- Water level prior to purging;
- Total well depth;
- Purge volume;
- Water level after purging;
- Well condition;
- Sampler's identification;
- Field measurements of pH, temperature, and specific conductivity; and
- Any other relevant information.

Ground water sampling information will be recorded on a ground water sampling form. Figure 3.8 shows an example of the form.

3.2.6 Laboratory Analyses

Laboratory analyses will be performed on all ground water samples and quality assurance/quality control (QA/QC) samples described in Section 5. The analytical methods for this sampling event are listed in Table 3.1.

Prior to sampling, arrangements will be made with the USEPA Mobile Laboratory to provide a sufficient number of appropriate sample containers for the samples to be collected. All containers, preservatives, and shipping requirements will be consistent with USEPA Mobile Laboratory protocol or those reported in Appendix A of this plan.

USEPA Mobile Laboratory personnel will specify the necessary QC samples and will notify the laboratory so that they can prepare these bottles. For samples requiring chemical preservation, preservatives will be added to containers by the laboratory prior to shipping. Shipping containers, ice chests with adequate padding, and cooling media will be sent by the laboratory to the site. Sampling personnel will fill the sample containers and return the samples to the laboratories.

3.3 AQUIFER TESTING

Slug tests will be conducted to estimate the hydraulic conductivity of the shallow saturated zone. Pumping tests will not be conducted because large quantities of potentially contaminated water are generated and must be treated or disposed of. A slug test is a single-well hydraulic test used to determine the hydraulic conductivity of an aquifer in the immediate vicinity of the tested well. Slug tests are best used for both confined and unconfined aquifers that have a transmissivity of less than 7,000 square feet per day (ft^2/day). Slug testing can be performed using either a rising head or a falling head test; at KSA, both methods will be used in sequence.

3.3.1 Definitions

- **Hydraulic Conductivity (K).** A quantitative measure of the ability of porous material to transmit water; defined as the volume of water that will flow through a unit cross-sectional area of porous or fractured material per unit time under a unit hydraulic gradient.
- **Transmissivity (T).** A quantitative measure of the ability of an aquifer to transmit water. It is the product of the hydraulic conductivity and the saturated thickness.
- **Slug Test.** Two types of testing are possible: a rising head or falling head test. A slug test consists of adding a slug of water or a solid cylinder of known volume to the well to be tested or removing a known volume of water or a cylinder and measuring the rate of recovery of water level inside the well. The slug of a known volume acts to raise or lower the water level in the well.
- **Rising Head Test.** A test used in an individual well within the saturated zone to estimate the hydraulic conductivity of the surrounding formation by lowering the water level in the well and measuring the rate of recovery of the water level. The water level may be lowered by pumping, bailing or removing a submerged slug from the well.
- **Falling Head Test.** A test used in an individual well to estimate the hydraulic conductivity of the surrounding formation by raising the water level in the well by

inserting a slug or quantity of water, and then measuring the rate of drop in the water level.

3.3.2 Equipment

The following equipment is needed to conduct a slug test:

- Teflon[®], PVC, or metal slugs;
- One-quarter inch nylon or polypropylene rope;
- Electric water level indicator;
- Pressure transducer/sensor;
- Field logbook/forms; and
- Automatic data recording instrument (such as the Hermit Environmental Data Logger[®], In-Situ, Inc. Model SE1000B or equal).

3.3.3 Test Methods, General

Aquifer hydraulic conductivity tests (slug tests) are accomplished by either removal of a slug or quantity of water (rising head) or introduction of a slug (falling head), and then allowing the water level to stabilize while taking water level measurements at closely spaced time intervals.

Prior to testing, the monitoring well must be thoroughly developed as described in Section 3.1.2.6 and water levels allowed to stabilize. Slug testing will proceed only after water level measurements show that static water level equilibrium has been achieved. During the slug test, the water level change should be influenced only by the introduction (or subtraction) of the slug volume. Other factors, such as inadequate well development, or extended pumping, may lead to inaccurate results. It is up to the field hydrogeologist to decide when static equilibrium has been reached in the well. The pressure transducer, slugs, and any other downhole equipment will be decontaminated prior to and immediately after the performance of the slug test using the procedures described in Section 3.2.2.1.

3.3.5 Falling Head Test

The falling head test is the first step in the two-step slug testing procedure. The following steps describe the falling head test.

1. Decontaminate all downhole equipment prior to initiating the test.
2. Open the well. Where wells are equipped with watertight caps, the well should be unsealed at least 24 hours prior to testing to allow the water level to stabilize. The protective casing will remain locked during this time to prevent vandalism.
3. Prepare the Aquifer Test Data form (Figure 3.9) with entries for:
 - Borehole/Well number;
 - Project number;
 - Project name;
 - Aquifer testing team;
 - Climatic data;
 - Ground surface elevation;
 - Top of well casing elevation;
 - Identification of measuring equipment used;
 - Page number;
 - Static water level;
 - Date; and
 - Time intervals (0,1,3,5,7,9,10, and 12 minutes and every three minutes thereafter through 60 elapsed minutes, then in 10-minute intervals for the next hour, and in 30-minute intervals for the next 3 hours).
4. Measure the static water level in the well to the nearest 0.01 foot.
5. Lower the decontaminated pressure transducer into the well and allow the displaced water to return to its static level. This can be determined by making periodic water level measurements until the static water level in the well is within 0.01 foot of the original static water level.
6. Lower the decontaminated slug into the well to just above the water level in the well.
7. Turn on the data logger and quickly lower the slug below the water table, being careful not to disturb the pressure transducer. Follow the owner's manual for proper operation of the data logger.
8. Terminate data recording when the water level stabilizes in the well.

Aquifer Slug Test Data Sheet

Location _____	Client _____	Well No. _____
Job No. _____	Field Scientist _____	Date _____
Water Level _____	Total Well Depth _____	
Measuring Datum _____	Elevation of Datum _____	
Weather _____	Temp _____	
Comments _____		

[illegible]

3.3.6 Rising Head Test

After completion of the falling head test, the rising head test will be performed. The following steps describe the rising head slug test procedure.

1. Measure the static water level in the well to the nearest 0.01 foot to ensure that it has returned to the static water level.
2. Initiate data recording and quickly withdraw the slug from the well. Follow the owner's manual for proper operation of the data logger.
3. Terminate data recording when the water level stabilizes in the well. Remove the pressure transducer from the well and decontaminate.

3.3.7 Slug Test Data Analysis

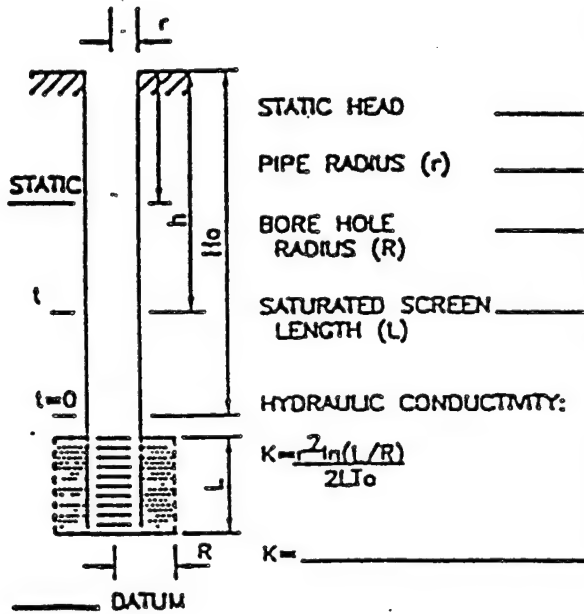
Data obtained during slug testing will be analyzed using AQTESOLV and the method of Hvorslev (1951) for confined aquifers or the method of Bouwer and Rice (1976) and Bouwer (1989) for unconfined conditions. The standard slug test form (Figure 3.10) is based on equations and test methods developed by Hvorslev (1951). Figure 3.11 is the Bouwer and Rice Analysis Data Form. Figure 3.12 contains the dimensionless parameters A, B, and C used for the Bouwer and Rice analysis.

Figure 3.10
Standard Slug Test Form/
Hvorslev Analysis

HVORSLEV'S METHOD FOR K

PROJECT _____
 WELL NUMBER _____
 DATE _____

LOCATION _____
 ELEVATION _____



TIME (MIN)	WATER DEPTH (FT)	RECOVERY TO STATIC \pm (WATER DEPTH-STAT)	$\frac{h}{H_0}$
STATIC		_____	_____
00		(H ₀)	1.00
		(h)	
		(h)	
		(h)	
		(h)	
		(h)	
		(h)	
		(h)	
		(h)	
		(h)	
		(h)	
		(h)	
		(h)	
		(h)	

K= _____ FT/MIN K= _____ FT/DAY K= _____ CM/SEC

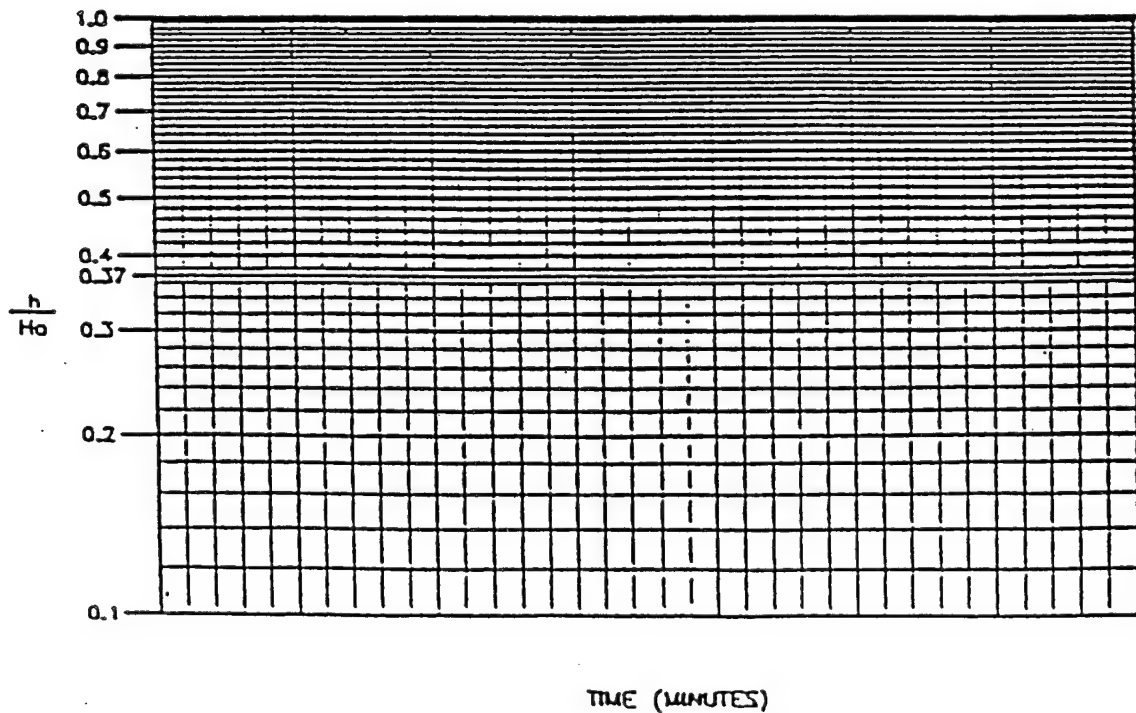
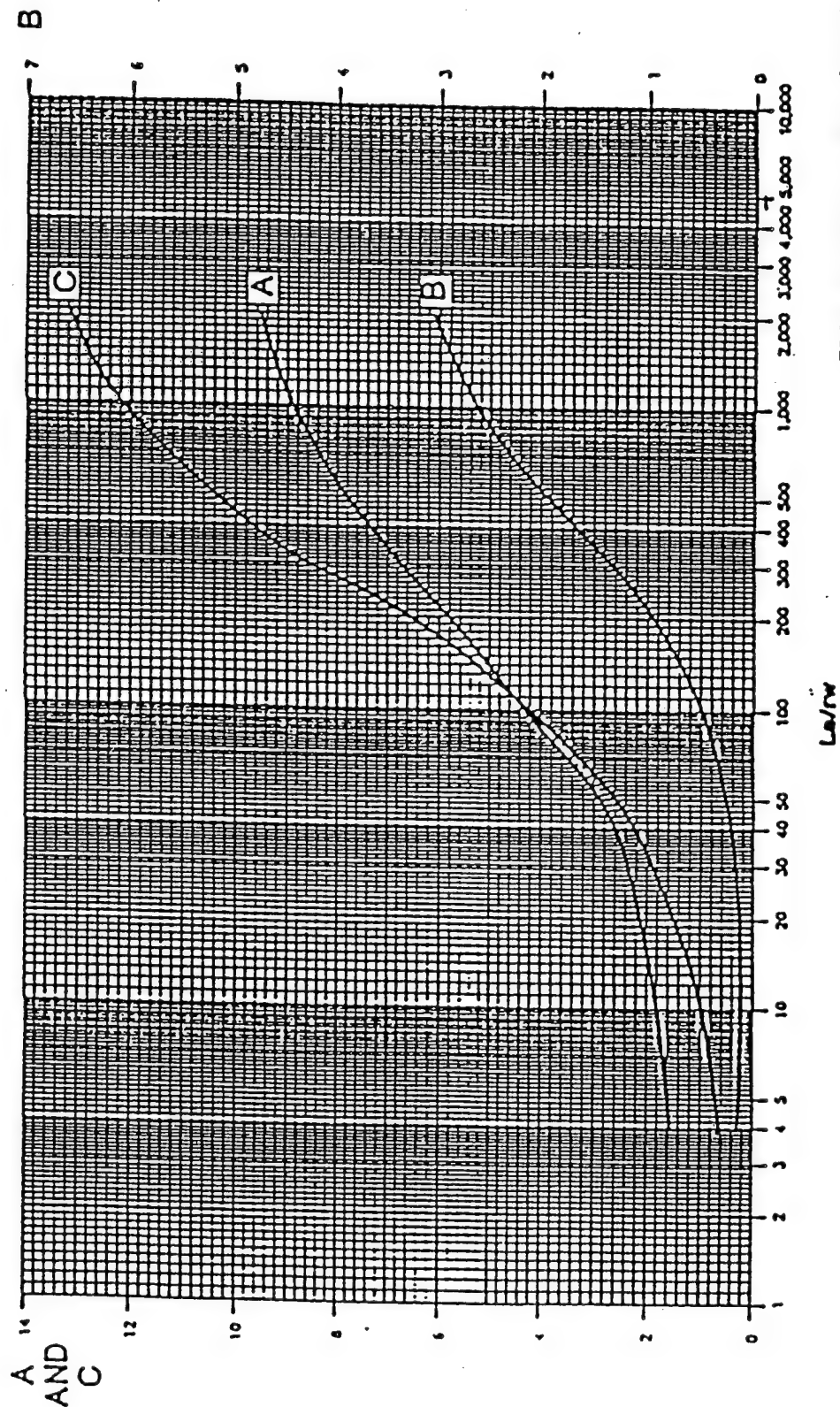


Figure 3.12
Bouwer and Rice Analysis
Dimensionless Parameters

DIMENSIONLESS PARAMETERS A, B, AND C
FOR AQUIFER TEST ANALYSIS



FROM BOUWER & RICE (1976)

SECTION 4

REMEDIAL OPTION EVALUATION AND EE/CA REPORT

Upon completion of field work, the Bioplume II[®] numerical ground water models will be used to determine the fate and transport of fuel hydrocarbons dissolved in ground water at each site. Based upon model predictions of contaminant concentration and distribution through time, and upon potential exposure pathways, the potential risk to human health and the environment will be assessed. If it is shown that intrinsic remediation of BTEX compounds is sufficient to reduce the potential risk to human health and the environment to acceptable levels, ES will recommend implementation of intrinsic remediation with long-term monitoring as the preferred remedial option. If intrinsic remediation is chosen, ES will prepare a site-specific, long-term monitoring plan which will specify the location of point-of-compliance monitoring wells and sampling frequencies.

If the intrinsic remediation remedial option is deemed inappropriate for use at either site, institutional controls such as ground water or land use restrictions will be evaluated to determine if they will be sufficient to reduce the risk to human health and the environment to acceptable levels. If institutional controls are deemed inappropriate, remedial options which could reduce risks to acceptable levels will be evaluated and the most appropriate remedial option identified. Potential active remedial options include free-phase product recovery, ground water pump-and-treat, and air sparging.

Upon completion of Bioplume II[®] modeling and remedial option selection, a report detailing the results of the modeling and remedial option selection will be prepared for each site. This report will follow the outline presented in Figure 4.1 and will contain an introduction, site description, identification of remediation objectives, description of remediation alternatives, an analysis of remediation alternatives, and the recommended remedial approach. This report will also contain the results of the site characterization activities described herein and a description of the Bioplume II[®] model developed for the site.

FIGURE 4.1

EXAMPLE EE/CA REPORT OUTLINE

INTRODUCTION

SITE DESCRIPTION

- Background
- Soil and Ground Water Characteristics
- Site Contamination

IDENTIFICATION OF REMEDIATION OBJECTIVES

- Potential Pathways for Human/Ecological Contact
- Chemical-Specific Applicable or Relevant and Appropriate Requirements (ARARs)

DESCRIPTION OF REMEDIATION ALTERNATIVES

- Intrinsic Remediation/Long-Term Monitoring
- Alternative 2 (Site-Specific)
- Alternative 3 (Site-Specific)

ANALYSIS OF REMEDIATION ALTERNATIVES

- Protectiveness (Bioplume II[®] Model Results & Discussion)
- Implementability
 - *Technical*
 - *Administrative (Political)*
- Cost
 - *Capital Costs*
 - *Operating Costs*
 - *Present-Worth Cost*

RECOMMENDED REMEDIATION APPROACH

- How does the chosen technology offer adequate protection for less cost?

APPENDIX A: Supporting Data and Documentation

APPENDIX B: Site-Specific Bioplume II[®] Model Input and Results

SECTION 5

QUALITY ASSURANCE/QUALITY CONTROL

Field QA/QC procedures will include collection of field duplicates and rinseate, field, and trip blanks; decontamination of the water-level probe and cable; use of analyte-appropriate containers; and chain-of-custody procedures for sample handling and tracking. All samples to be transferred to the EPA Mobile Laboratory will be clearly labeled to indicate sample number, location, matrix (e.g., ground water), and analyses requested. Samples will be preserved in accordance with the analytical methods to be used, and water sample containers will be packed in coolers with ice to maintain a shipping temperature of 4°C.

All field sampling activities will be recorded in a bound, sequentially paginated field notebook in permanent ink. All sample collection entries will include the date, time, sample locations and numbers, notations of field observations, and the sampler's name and signature. Field QC samples will be collected in accordance with the program described below, and as summarized in Table 5.1.

QA/QC sampling will include collection and analysis of duplicate samples, rinseate blanks, field/trip blanks, and matrix spike samples. Internal laboratory QC analyses will involve laboratory control samples (LCSs) and laboratory method blanks (LMBs). QA/QC objectives for each of these samples, blanks, and spikes are described below.

One duplicate water sample will be taken for every 10 or fewer GROUND WATER samples. Duplicate water samples will be analyzed for VOCs.

One rinseate sample will be collected for every 10 or fewer water samples. Because disposable bailers are proposed for this sampling event, the rinseate sample will consist of a sample of distilled water poured into a bailer and subsequently transferred into a sample container provided by the laboratory. Rinseate samples will be analyzed for VOCs.

TABLE 5.1
QC SAMPLING PROTOCOL
SITES FT01 AND SS12
KING SALMON AIRPORT, ALASKA

QA/QC Sample Types	Frequency Collected and/or Analyzed	Analytical Methods
Duplicates	One per 10 or fewer samples (10%)	VOCs
Rinseate Blanks	One per 10 or fewer samples (10%)	VOCs
Field Blanks	One per 20 or fewer samples (5%)	VOCs
Trip Blanks	One per shipping cooler	VOCs
Matrix Spike Samples	One per sampling event	VOCs
Laboratory Control Sample	One per method per medium	Laboratory Control Charts (Method Specific)
Laboratory Method Blanks	One per method per medium	Laboratory Control Charts (Method Specific)

A field blank will be collected for every 20 or fewer water samples to assess the effects of ambient conditions in the field. The field blank will consist of a sample of distilled water poured into a laboratory-supplied sample container while sampling activities are underway. The field blank will be analyzed for VOCs.

A trip blank will be analyzed to assess the effects of ambient conditions and conditions on sampling results during the transportation of samples. The trip blank will be prepared by the laboratory and will be transported inside one of the coolers containing samples. This sample will be analyzed for VOCs.

Matrix spikes will be prepared in the laboratory and used to establish matrix effects for samples analyzed for VOCs.

LCSs and LMBs will be prepared internally by the laboratory and will be analyzed each day samples from the site are analyzed. Samples will be re-analyzed in cases where the LCS or LMB are out of the control limits. Control charts for LCSs and LMBs will be developed by the laboratory and monitored for the analytical methods used.

SECTION 6

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APPENDIX A

**CONTAINERS, PRESERVATIVES, PACKAGING, AND SHIPPING
REQUIREMENTS FOR SOIL AND GROUND WATER SAMPLES**

Appendix A - Soil and Ground Water Analytical Protocol

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Soil	Dehydrogenase enzyme activity (optional)	Colorimetric RSKSOP-100	Reduction of added triphenyltetrazolium chloride by soil microbes is measured colorimetrically	An indicator of the presence of soil microbes, which are necessary for bioremediation to occur	At the beginning of the project	Collect 100 g of soil in a glass container; cool to 4°C	Field
Soil	Aromatic hydrocarbons (benzene, toluene, ethylbenzene, and xylene [BTEX]; trimethylbenzene isomers)	Purge and trap gas chromatography (GC) method SW8020	Handbook method modified for field extraction of soil using methanol	Data is used to determine the extent of soil contamination, the contaminant mass present, and the need for source removal	Each sampling round	Collect 100 g of soil in a glass container with Teflon-lined cap; cool to 4°C	Fixed-base
Soil	Total organic carbon (TOC)	SW9060 modified for soil samples	Procedure must be accurate over the range of 0.5–15 percent TOC	Relatively high amounts of TOC may be indicative of a reducing environment and may indicate the need for analysis of electron acceptors associated with that environment; the rate of migration of petroleum contaminants in groundwater is dependent upon the amount of TOC in the saturated zone soil; the rate of release of petroleum contaminants from the source into groundwater is dependent (in part) on the amount of TOC in the vadose zone soil	At initial sampling	Collect 100 g of soil in a glass container with Teflon-lined cap; cool to 4°C	Fixed-base

Appendix A - Continued

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Soil	Total hydrocarbons, volatile and extractable	GC method SW8015 [modified]	Handbook method; reference is the California LUFT manual	Data is used to determine the extent of soil contamination, the contaminant mass present, and the need for source removal	Each sampling round	Collect 100 g of soil in a glass container with Teflon-lined cap; cool to 4°C	Fixed-base
Soil	Moisture	ASTM D-2216	Handbook method	Data is used to correct soil sample analytical results for moisture content (e.g., report results on a dry weight basis)	Each soil sampling round	N/A	Fixed-base
Water	Ferrous (Fe ²⁺)	Colorimetric A3500-Fe D	Field only	May indicate an anaerobic degradation process due to depletion of oxygen, nitrate, and manganese	Each sampling round	Collect 100 mL of water in a glass container; acidify with hydrochloric acid	Field
Water	Ferrous (Fe ²⁺)	Colorimetric HACH 25140-25	Alternate method; field only	May indicate an anaerobic degradation process due to depletion of oxygen, nitrate, and manganese	Each sampling round	Collect 100 mL of water in a glass container; acidify with hydrochloric acid	Field
Water	Temperature	E170.1	Field only	Well development	Each sampling round	N/A	Field
Water	Chloride	Mercuric nitrate titration A4500-Cl ⁻ C	Ion chromatography (IC) method E300 or method SW9050 may also be used	General water quality parameter used as a marker to verify that site samples are obtained from the same groundwater system	Each sampling round	Collect 250 mL of water in a glass container and protect from sunlight; analyze immediately	Field
Water	Oxygen	Dissolved oxygen meter	Refer to method A4500 for a comparable laboratory procedure	The oxygen concentration is a data input to the Bioplume model; concentrations less than 1 mg/L indicate an anaerobic pathway	Each sampling round	Collect 300 mL of water in biochemical oxygen demand bottles; analyze immediately; alternately, measure dissolved oxygen <i>in situ</i>	Field

Appendix A - Continued

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	pH	E150.1/SW9040, direct reading meter	Protocols/Handbook methods	Aerobic and anaerobic processes are pH-sensitive	Each sampling round	Collect 100–250 mL of water in a glass or plastic container; analyze immediately	Field
Water	Conductivity	E120.1/SW9050, direct reading meter	Protocols/Handbook methods	General water quality parameter used as a marker to verify that site samples are obtained from the same groundwater system	Each sampling round	Collect 100–250 mL of water in a glass or plastic container	Field
Water	Alkalinity	A2320, titrimetric; E310.2, colorimetric	Handbook method	General water quality parameter used (1) as a marker to verify that all site samples are obtained from the same groundwater system and (2) to measure the buffering capacity of groundwater	Each sampling round	Collect 250 mL of water in a glass or plastic container; analyze within 6 hours	Field
Water	Redox potential	A2580 B	Measurements are made with electrodes; results are displayed on a meter; samples should be protected from exposure to atmospheric oxygen	The redox potential of groundwater influences and is influenced by the nature of the biologically mediated degradation of contaminants; the redox potential of groundwater may range from more than 200 mV to less than -400 mV	Each sampling round	Collect 100–250 mL of water in a glass container; analyze immediately	Field
Water	Nitrate (NO_3^-)	IC method E300 or method SW9056; colorimetric, method E353.2	Method E300 is a Handbook method; method SW9056 is an equivalent procedure	Substrate for microbial respiration if oxygen is depleted	Each sampling round	Collect up to 40 mL of water in a glass or plastic container; cool to 4°C	Fixed-base

Appendix A - Continued

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Sulfate (SO_4^{2-})	IC method E300 or method SW9056	Method E300 is a Handbook method; method SW9056 is an equivalent procedure	Substrate for anaerobic microbial respiration when the redox potential is approximately -200 mV; determined when the oxygen concentration is less than 6 mg/L and the redox measurement is less than 0 mV	Each sampling round	Collect up to 40 mL of water in a glass or plastic container; cool to 4°C	Fixed-base
Water	Sulfate (SO_4^{2-})	HACH SulfaVer 4 method	Photometric	Substrate for anaerobic microbial respiration when the redox potential is approximately -200 mV; determined when the oxygen concentration is less than 6 mg/L and the redox measurement is less than 0 mV	Each sampling round	Collect up to 40 mL of water in a glass or plastic container; cool to 4°C	Field
Water	Dissolved sulfide (S^{2-})	A4500-S ² -B for the separation of dissolved and suspended sulfide; A4500-S ² -E for the colorimetric determination of dissolved sulfide	These procedures will determine dissolved sulfide, dissolved bisulfide, and dissolved hydrogen sulfide as sulfide; the concentration of hydrogen sulfide can be derived from the table in method A4500-S ² -F, if required	Products of sulfate-based anaerobic microbial respiration; analyze in conjunction with sulfate analysis	Each sampling round	Collect 250 mL of water in a glass container; cool to 4°C; add zinc acetate and sodium hydroxide to pH greater than 8	Fixed-base

Appendix A - Continued

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Methane; carbon dioxide	RSKSOP 147 uses flame ionization detection for ppm levels of methane (see note 10 for literature reference)	Method published and used by the U.S. Environmental Protection Agency (EPA) Robert S. Kerr Laboratory	The presence of methane suggests BTEX degradation via an anaerobic pathway utilizing carbon dioxide (carbonate) as the electron acceptor (methanogenesis); a redox potential measurement of less than -200 mV could be indicative of methanogenesis and should be followed by the analysis referenced here; the presence of free carbon dioxide dissolved in groundwater is unlikely because of the carbonate buffering system of water, but if detected, the carbon dioxide concentrations should be compared with background to determine whether they are elevated; elevated concentrations of carbon dioxide could indicate an aerobic mechanism for bacterial degradation of petroleum	Each sampling round	Collect water samples in 40 mL volatile organic analysis (VOA) vials with Teflon-lined caps; cool to 4°C	Fixed-base Laboratory

Appendix A - Continued

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Carbon dioxide	HACH 1436-01	Titrimetric; alternate method	The presence of free carbon dioxide dissolved in groundwater is unlikely because of the carbonate buffering system of water, but if detected, the carbon dioxide concentrations should be compared with background to determine whether they are elevated; elevated concentrations of carbon dioxide could indicate an aerobic mechanism for bacterial degradation of petroleum	Each sampling round	N/A	Field
Water	Aromatic hydrocarbons (BTEX, trimethylbenzene isomers)	Purge and trap GC method SW8020	Handbook method; analysis may be extended to higher molecular weight alkyl benzenes	Method of analysis for BTEX, which is the primary target analyte for monitoring natural attenuation; BTEX concentrations must also be measured for regulatory compliance; method can be extended to higher molecular weight alkyl benzenes; trimethylbenzenes are used to monitor plume dilution if degradation is primarily anaerobic	Each sampling round	Collect water samples in a 40 mL VOA vial; cool to 4°C; add hydrochloric acid to pH 2	Fixed-base

Appendix A - Continued

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Total hydrocarbons, volatile and extractable (optional)	GC method SW8015 [modified]	Handbook method; reference is the California LUFT manual	Data used to monitor the reduction in concentrations of total fuel hydrocarbons (in addition to BTEX) due to natural attenuation	One time per year or as required by regulations	Volatile hydrocarbons—collect water samples in a 40 mL VOA vial; cool to 4°C; add hydrochloric acid to pH 2 Extractable hydrocarbons—collect 1 L of water in a glass container; cool to 4°C; add hydrochloric acid to pH 2	Fixed-base
Water	Polycyclic aromatic hydrocarbons (PAHs) (optional)	GC/mass spectroscopy method SW8270; high-performance liquid chromatography method SW8310	Analysis needed only for several samples per site	PAHs are components of fuel and are typically analyzed for regulatory compliance; data on their concentrations are not used currently in the evaluation of natural attenuation	At initial sampling and at site closure or as required by regulations	Collect 1 L of water in a glass container; cool to 4°C	Fixed-base
Water	Total fuel carbon (optional)	Purge and trap GC method SW8020 modified to measure all volatile aromatic hydrocarbons present in the sample	A substitute method for measuring total volatile hydrocarbons; reports amount of fuel as carbon present in the sample; method available from the U.S. EPA Robert S. Kerr Laboratory	Data used to monitor the reduction in concentrations of total fuel hydrocarbons (in addition to BTEX) due to natural attenuation	At initial sampling and at site closure	Collect 40 mL of water in glass vials with Teflon-lined caps; add sulfuric acid to pH 2; cool to 4°C	Fixed-base

Appendix A - Continued

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Dissolved organic carbon (DOC)	A5310 C	An oxidation procedure whereby carbon dioxide formed from DOC is measured by an infrared spectrometer. The minimum detectable amount of DOC is 0.05 mg/L	A measure of the availability of nutrients in groundwater for biological activity	Each sampling round	Collect 100 mL of water in an amber glass container with Teflon-lined cap; preserve with sulfuric acid to pH less than 2; cool to 4°C	Fixed-base

1. "HACH" refers to the HACH Company catalog, 1990.
2. "A" refers to *Standard Methods for the Examination of Water and Wastewater*, 18th edition, 1992.
3. "E" refers to *Methods for Chemical Analysis of Water and Wastes*, U.S. Environmental Protection Agency, March 1979.
4. "Protocols" refers to the *Environmental Chemistry Function Installation Restoration Program Analytical Protocols*, 11 June 1992.
5. "Handbook" refers to the *Handbook to Support the Installation Restoration Program (IRP) Remedial Investigations and Feasibility Studies (RI/FS)*, September 1993.
6. "SW" refers to the *Test Methods for Evaluating Solid Waste, Physical, and Chemical Methods*, SW-846, U.S. Environmental Protection Agency, 3rd edition, 1986.
7. "ASTM" refers to the *American Society for Testing and Materials*, current edition.
8. "RSKSOP" refers to Robert S. Kerr (*Environmental Protection Agency Laboratory Standard Operating Procedure*).
9. "LUFT" refers to the state of California *Leaking Underground Fuel Tank Field Manual*, 1988 edition.
10. *International Journal of Environmental Analytical Chemistry*, Volume 36, pp. 249-257, "Dissolved Oxygen and Methane in Water by a Gas Chromatography Headspace Equilibration Technique," by D. H. Kampbell, J. T. Wilson, and S. A. Vandegrift.